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TO THE
STUDENTS
AT THE
UNIVERSITY of EDINBURGH,
AND ALL OTHER
LOVERS OF CHYMISTRY,

This new Edition of the celebrated M. MACQUER's
ELEMENTS of CHYMISTRY, is

Humbly Dedicated

Edin. Nov. 3.

By

1768.

THE PUBLISHER.

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THE
AUTHOR'S
PREFACE.

AN hundred and fifty years are scarce elapsed since the clouds of prejudice, which had long overspread the world, began to clear up, and men were convinced, by cultivating the sciences, and attending to Nature, that no fanciful hypotheses would ever lead them to the true causes of those various phenomena that incessantly and every where meet the observer's eye ; but that the narrow limits of the human understanding confine the course of our researches to one single path ; namely, that of experiment, or the use of our senses. Yet, in this short period, natural philosophy hath risen to a high pitch of improvement, and may with truth be said to have made much greater advances towards perfection, since the experimental method was introduced, than in the many ages before.

This is true with regard to every branch of natural philosophy ; but more particularly with regard to chymistry. Though this science cannot be said to have ever existed without experiments, yet it laboured under the same disadvantages with the rest ; because those, who studied it, made all their experiments with a view to confirm their own hypotheses, and in consequence of principles, which had

no foundation whatever but in their wild imaginations.

Hence arose that enormous heap, that incongruous jumble of facts, which some time ago constituted all the knowledge of chymists. Most of them, and especially those who assumed the pompous title of alchymists, were persuaded that all the metals were no other than nature's rude unfinished essays towards making gold; which, by means of due coction in the bowels of the earth, advanced gradually towards maturity, till at last they were perfectly converted into that beautiful and precious metal.

On this principle, which, if not demonstrably false, is at least utterly destitute of proof, and unsupported by a single observation, they attempted to finish what Nature had begun, by procuring to the imperfect metals this much desired coction. To attain it, they made an infinite number of experiments and trials; which all conspired to detect the falsity of their system, and to satisfy men of sense, that the methods they employed were very far from answering the purpose.

However, as facts always promote the knowledge of nature, it happened that those experiments, tho' quite useless with regard to the end for which they were originally made, proved the occasion of several curious discoveries.

These lucky consequences of their mistaken labours raised the courage of the chymists, or rather alchymists, who looked upon every such instance of success as a new step towards the grand work, and greatly increased the fond opinion they entertained of themselves, and of their art, which on that account they set up very high above all other sciences. Nay, they carried this notion of superiority so far, as to hold the rest of mankind unworthy, or incapable, of rising to such sublime knowledge. In consequence thereof, chymistry be-

came

came an occult and mysterious science; its expressions were all tropes and figures, its phrases metaphorical, and its axioms so many enigmas: in short, an obscure unintelligible jargon is the justest character of the alchymistic language.

Thus, by endeavouring to conceal their secrets, those gentlemen rendered their art useless to mankind, and brought it into deserved contempt. But, at length the genius of true philosophy prevailed in chymistry, as well as in the other sciences. Some great men arose, who had generosity enough to think their knowledge no otherways valuable than as it proved of service to society. They did their utmost to introduce both the knowledge and the practice of many important secrets, till them of no use; they drew aside the veil which hid the charms of chymistry; and that science emerging from the profound obscurity, in which it had for many ages lain concealed, gained the admiration of the world as soon as it appeared in open day. Several societies of ingenious men were formed in the most learned countries of Europe, who vied with one another in their labours to execute the noble scheme, and assisted each other by mutually communicating their discoveries. Chymistry made the most rapid progress, enriching and perfecting the arts derived from, or depending on it. In a word, it put on a new face, and became truly worthy of the title of science; founding its principles and its processes on solid experiments, and on just consequences deduced from them.

Since that time the art is become so extensive, by the numerous discoveries which chymists have already made, and are daily making, that large volumes are required to contain a complete treatise on the subject. In short, chymistry may now, in some degree, be compared to geometry; each of these sciences takes in a most ample field of enquiry, which every day enlarges very considerably; from

each are derived several arts, not only useful but even necessary to society; each hath its axioms and its undeniable principles, either demonstrated from internal evidence, or founded on constant experience; so that the one, as well as the other, may be reduced to certain fundamental truths, on which all the rest are built. These fundamental truths, connected together, and laid down with order and precision, form what we call the elements of a science. It is well known, that there are many such works relating to geometry, but it is not so with regard to chymistry; there being very few books which treat of this science in an elementary manner.

Yet it must be owned, that performances of this kind are exceedingly useful. Many who have a relish for the sciences, but have not leisure to read elaborate works which treat of them minutely, are glad to meet with a book from which, without sacrificing too much of their time, or neglecting their ordinary business, they may obtain a taste or just notion of a science that is not their principal study. Those who incline to go further, and learn more, may, by reading an elementary tract, be enabled to understand authors who, as they commonly write only for proficients in the art, are obscure and hardly intelligible to mere beginners. Nay, I presume to say, that an elementary treatise of chymistry may prove a very useful book, even to those who have made some progress in the science: for, as it contains only the fundamental propositions, and indeed is an abstract of the whole art, it may help them to recollect the most important parts of what they have read in many different works, and fix in their memories the most essential truths, which might else be either confounded with others, or entirely forgot. And these are the motives which determined me to compose the work which I now offer to the public.

The general plan on which I proceed is to suppose

I propose my reader an absolute novice in chymistry ; to lead him from the most simple truths, and such as imply the lowest degree of knowledge, to such as are more complex, and require a greater acquaintance with nature. This order, which I have laid down for my rule, hath obliged me to begin with examining the most simple substances that we know, and which we consider as the elements whereof others are composed ; as, by knowing the properties of these elementary parts, we are naturally led to those of their several combinations ; and on the other hand, in order to know the properties of compound bodies, it is necessary we should be first acquainted with the properties of their principles. The same reason induced me, when enquiring into the properties of one substance, to take no notice of those which relate to any other substance not treated of before. For example : as I treat of acids before metals, I say nothing under the head of those acids concerning their power of dissolving metals : that I defer till I come to the subject of metals : and thus I avoid speaking prematurely of a substance with which I suppose my reader wholly unacquainted. And this method I was so much the more easily induced to follow, that I know of no chymical book written on the same plan.

After discoursing of elements in general, I treat next of such substances as are immediately composed of them, and are, next to them, the most simple : such are all saline substances. This head comprehends mineral acids, fixed alkalis, and their several combinations ; the volatile sulphureous spirit, sulphur, phosphorus, and the neutral salts which have an earth or fixed alkali for their basis ; those which have for their basis either a volatile alkali, or some metallic substance, are referred, according to my general plan, to the heads under which I treat of those substances.

Metallic substances are scarcely more compound-

ed than the saline; which induces me to consider them next. I begin with those which are the most simple, or at least seem to be so; because their principles, being very strongly connected together, are separated with the greatest difficulty: such are the metals properly so called: namely Gold, Silver, Copper, Iron, Tin, and Lead. After these come the semi-metals in order; to wit, Regulus of Antimony, Zinc, Bismuth, and Regulus of Arsenic. Mercury being a doubtful substance, which some chymists rank with the metals, and others with the semi-metals, because it actually possesses certain properties in common with each, I have treated of it in a separate chapter, which stands between the metals and semi-metals.

I next proceed to examine the several sorts of oils, whether vegetable, which are divided into fat, essential, and empyreumatic; or animal, and mineral oils.

By examining these substances we obtain ideas of all the principles which enter into the composition of vegetable and animal bodies; that is, of those substances that are capable of fermentation; this enables me to treat of fermentation in general; of its three different degrees or kinds, the spirituous, acetous, and putrid; and of the products of those fermentations, ardent spirits, acids analogous to those of vegetables and animals, and volatile alkalis.

The order in which I treat of all these substances being different from that in which they are obtained from compound bodies, I give, in a distinct chapter, a general idea of chymical decomposition with a view to shew the order in which they are separated, from the several bodies in the composition whereof they are found. This brings them a second time under review, and gives me an opportunity of distinguishing those which exist naturally in compound bodies, from those which are only

P R E F A C E

xi

the result of a new combination of some of their principles produced by the fire.

The succeeding chapter explains the late Mr. Geoffroy's table of affinities ; which I take to be of great use at the end of an elementary tract like this as it collects into one point of view the most essential and fundamental doctrines which are dispersed through the work.

I conclude with an account of the construction of such vessels and furnaces as are usually employed in chymistry.

In this part I say nothing of any manual operations, or the several ways of performing chymical processes ; reserving these particulars for my treatise of practical chymistry, to which this must be considered as an introduction.



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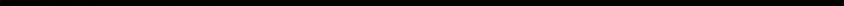
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CONTENTS of VOL. I.

Elements of the THEORY of Chymistry.

CHAP. I.

O <i>F the Principles of Bodies</i>	page	1
§ 1. Of Air		3
§ 2. Of Water		4
§ 3. Of Earth		5
§ 4. Of Fire		7
§ 5. Of the Phlogiston		9
HAP. II. <i>A general View of the Relations or Affinities between Bodies</i>		11
HAP. III. <i>Of Saline Substances in general</i>		14
§ 1. Of Acids		16
§ 2. Of Alkalís		18
§ 3. Of Neutral Salts		20
HAP. IV. <i>Of the several Sorts of Saline Substances</i>		
§ 1. Of the Universal Acid		24
§ 2. Of the Nitrous Acid		29
§ 3. Of the Marine Acid		33
HAP. V. <i>Of Lime</i>		38
HAP. VI. <i>Of Metallic Substances in general</i>		45
HAP. VII. <i>Of Metals</i>		49
§ 1. Of Gold		50
§ 2. Of Silver		52
§ 3. Of Copper		59
§ 4. Of Iron		63
§ 5. Of Tin		69
§ 6. Of Lead		71
HAP. VIII. <i>Of Quick-Silver</i>		77
	CHAP.	

CHAP. IX. <i>Of the Semi-Metals</i>	
§ 1. Of Regulus of Antimony	Page 83
§ 2. Of Bismuth	91
§ 3. Of Zinc	93
§ 4. Of Regulus of Arsenic	95
CHAP. X. <i>Of Oil in general</i>	101
§ 1. Of Charcoal	102
§ 2. Of Soap	104
CHAP. XI. <i>Of the several Sorts of Oils</i>	
§ 1. Of Mineral Oils	105
§ 2. Of Vegetable Oils	106
§ 3. Of animal Oils.	109
CHAP. XII. <i>Of Fermentation in general</i>	110
CHAP. XIII. <i>Of the Spirituous Fermentation</i>	111
CHAP. XIV. <i>Of the Acetous Fermentation</i>	120
§ 1. Of Vinegar	121
§ 2. Of Tartar	123
CHAP. XV. <i>Of the putrid Fermentation, or Putrefaction</i>	128
CHAP. XVI. <i>A general View of Chymical Decomposition</i>	135
§ 1. The analysis of vegetable substances	136
Emulsions	139
§ 2. The analysis of animal substances	142
§ 3. The analysis of mineral substances	144
Of the Pyrites	147
Of Ores	149
CHAP. XVII. <i>Explanation of the Table of Affinities.</i>	159
CHAP. XVIII. <i>The Theory of constructing the Vessels most commonly used in Chymistry</i>	168
CHAP. XIX. <i>The Theory of constructing the Furnaces most commonly used in Chymistry.</i>	178
Of Lutes	197

Elements of the PRACTICE of Chymistry.

Introduction

PART I. OF MINERALS.

SECTION I.

Operations performed on saline mineral substances.

CHAP

CONTENTS.

xv

CHAP. I. *Of the Vitriol Acid.*

1. PROCESS. To extract vitriol from the pyrites
page 211
2. To extract sulphur from the pyrites, and other
sulphureous minerals 216
3. To extract alum from aluminous minerals 220
4. To extract the vitriolic acid from copperas or
green vitriol 227
5. To decompose sulphur, and extract its acid,
by burning it 232
6. To concentrate the vitriolic acid 236
7. To decompose vitriolated tartar by means
of the phlogiston; or to compose sulphur by
combining the vitriolic acid with the phlogi-
ston 239

CHAP. II. *Of the Nitrous acid.*

1. PROCESS. To extract nitre out of nitrous
earths and stones. The purification of salt-
petre. Mother of nitre. Magnesia 242
2. To decompose nitre by means of the phlo-
giston. Nitre fixed by charcoal. *Glyssus* of
nitre. *Sal polychrestum*. 249
3. To decompose nitre by means of the vitriolic
acid. The smoking spirit of nitre. *Sal de*
duobus. The purification of spirit of nitre 255

CHAP. III. *Of the Marine Acid.*

1. PROCESS. To extract sea-salt from sea-wa-
ter, and from brine-springs. Epsom-salt 260
2. Experiments concerning the decomposition of
sea-salt by means of the phlogiston. Kunc-
kel's phosphorus 264
3. To decompose sea-salt by means of the vitri-
olic acid. Glauber salt. The purification and
concentration of spirit of salt 282
4. To decompose sea-salt by means of the ni-
trous acid. *Aqua regis*. Quadrangular nitre 290

CHAP. IV. *Of Borax*

291

THE

CONTENTS

1. Preface. To explain the nature of the work, and to show the necessity of it. 1

2. To explain the nature of the work, and to show the necessity of it. 1

3. To explain the nature of the work, and to show the necessity of it. 1

4. To explain the nature of the work, and to show the necessity of it. 1

5. To explain the nature of the work, and to show the necessity of it. 1

6. To explain the nature of the work, and to show the necessity of it. 1

7. To explain the nature of the work, and to show the necessity of it. 1

8. To explain the nature of the work, and to show the necessity of it. 1

9. To explain the nature of the work, and to show the necessity of it. 1

10. To explain the nature of the work, and to show the necessity of it. 1

11. To explain the nature of the work, and to show the necessity of it. 1

12. To explain the nature of the work, and to show the necessity of it. 1

13. To explain the nature of the work, and to show the necessity of it. 1

14. To explain the nature of the work, and to show the necessity of it. 1

15. To explain the nature of the work, and to show the necessity of it. 1

16. To explain the nature of the work, and to show the necessity of it. 1

17. To explain the nature of the work, and to show the necessity of it. 1

18. To explain the nature of the work, and to show the necessity of it. 1

19. To explain the nature of the work, and to show the necessity of it. 1

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ERRATA.

Page 147. line 14, for *flour* read *fluor*.
—213, 215 (running title,) for *Theory*, read *Practice*.



E L E M E N T S

O F T H E

T H E O R Y of C H Y M I S T R Y.



C H A P. I.

Of the PRINCIPLES of Bodies.

I. *Of Air.* II. *Of Water.* III. *Of Earth.* IV. *Of Fire.* V. *Of the Phlogiston.*

TH E object and principal end of Chymistry is to separate the different substances that enter into the composition of bodies; to examine each of them separately; to discover their properties and relations; to decompose, if possible, those very substances; to compare them together, and combine them with others; to reunite them again into one body, so as to reproduce the original compound with all its properties; or even to produce new compounds that never existed among the works of nature, from mixtures of other matters differently combined.

VOL. I.

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But this analysis, or decomposition, of bodies is finite ; we being unable to carry it beyond a certain limit. In whatever way we attempt to go further, we are always stopped by substances in which we can produce no change, which will not admit of being resolved into others, and which stand as so many firm barriers obstructing our progress.

To these substances we may, in my opinion, give the title of Principles or Elements : at least, with regard to us, they are really such. Of this sort the principal are Earth, Water, Air, and Fire. For though there be ground to believe, that these are not the primary component parts, or the most simple elements, of matter ; yet, as we know by experience, that our senses cannot possibly discover the principles of which they are composed, it seems more reasonable to fix upon them, and consider them as simple homogeneous bodies, and the principles of the rest, than to fatigue our minds with vain conjectures about the parts or elements of which they may consist ; seeing there is no criterion by which we can know whether we have hit upon the truth, or whether the notions we have formed are mere fancies. We shall therefore consider these four substances as the principles or elements of all the various compounds which nature presents to our enquiries : because of all those we have as yet discovered, they are in fact the most simple ; and because all our decompositions, all our experiments on other bodies, plainly prove that they are at last resolvable into these primary parts.

These principles do not enter in the same proportion into all bodies : there are even some compounds in the composition of which this or that particular principle is not to be found. Thus Air and Water seem to be wholly excluded from the texture of Metals : at least all the experiments that

have

have hitherto been made on them seem to confirm this opinion.

The substances composed immediately of these *first* elements we shall call *secondary* principles; because in reality their several combinations with each other, the interchangeable coalitions that take place between them, constitute the different natures of all other bodies; which, as they result from the union both of primary and secondary principles, are properly entitled to the name of compounds or mixts.

Before we enter upon the examination of compound substances, it is necessary to consider with some attention the most simple ones, or our four *first* principles, in order to discover their chief properties.

§. I. Of AIR.

Air is that fluid which we constantly breathe, and which furrounds the whole surface of the terrestrial globe. Being heavy, like all other bodies, it penetrates into all places that are not either absolutely inaccessible, or filled with some other body heavier than itself. Its principal property is to be susceptible of condensation and rarefaction; so that the very same quantity of Air may occupy a much greater, or a much smaller space, according to the different state it is in. Heat and cold, or, if you will, the presence and the absence of the particles of Fire, are the most usual causes, and indeed the measures, of its condensation and rarefaction: for if a certain quantity of air be heated, its bulk increases in proportion to the degree of heat applied to it; the consequence of which is, that the same space now contains fewer particles of air than it did before. Cold again produces just the opposite effect.

On this property which air has, of being condensed.

densed and rarefied by heat, its elasticity, or springiness, chiefly depends. For if Air were forced into a less compass, by condensation, than it took up before, and then exposed to a very considerable degree of cold, it would remain quite inactive, without exerting such an effort as it usually makes against the compressing body. On the other hand, the elasticity of heated air arises only from hence, that being rarified by the action of fire, it requires much more space than it occupied before.

Air enters into the composition of many substances, especially vegetable and animal bodies: for by analysing most of them such a considerable quantity thereof is extricated, that some naturalists have suspected it to be altogether destitute of elasticity, when thus combined with the other principles in the composition of bodies. According to them the efficacy of the elastic power of the Air is so prodigious, and its force when compressed so excessive, that it is not possible the other component parts of bodies should be able to confine so much of it, in that state of compression which it must needs undergo, if retaining its elasticity it were pent up among them.

However that be, this elastic property of the air produces the most singular and important phenomena, observable in the resolution and composition of bodies.

§. II. *Of WATER.*

Water is a thing so well known, that it is almost needless to attempt giving a general idea of it here. Every one knows that it is a transparent, insipid substance, and usually fluid. I say it is usually so; for being exposed to a certain degree of cold it becomes solid: solidity therefore seems to be its most natural state.

Water exposed to the fire grows hot; but only

to a certain degree, beyond which its heat never rises, be the force of fire applied to it ever so violent: it is known to have acquired this degree of heat by its boiling up with great tumult. Water cannot be made hotter, because it is volatile, and incapable of enduring the heat, without being evaporated and entirely dissipated.

If such a violent and sudden heat be applied to water, as will not allow it time to exhale gently in vapours, as when, for instance, a small quantity thereof is thrown upon a metal in fusion, it is dissipated at once with vast impetuosity, producing a most terrible and dangerous explosion. This surprising effect may be accounted for from the instantaneous dilatation of the parts of the water itself; or rather of the air it contains. Moreover, water enters into the texture of many bodies, both compounds and secondary principles; but, like air, it seems to be excluded from the composition of all metals and most minerals. For although an immense quantity of water exists in the bowels of the earth, moistening all its contents, it cannot be thence inferred that it is one of the principles of minerals. It is only interposed between their parts; for they may be entirely divested of it, without any sort of decomposition: indeed it is not capable of an intimate connection with them.

§. III. *Of EARTH.*

We observed that the two principles above treated of are volatile; that is, the action of fire separates them from the bodies they help to compose, carrying them quite off, and dissipating them. That of which we are now to speak, namely Earth, is fixed, and, when it is absolutely pure, resists the utmost force of fire. So that, whatever remains of a body, after it hath been exposed to the power of the fiercest fire, must be considered as contain-

ing nearly all its earthly principle, and consisting chiefly thereof. I qualify my expression thus for two reasons: the first is, because it often happens, that this remainder does not actually contain all the earth which existed originally in the mixt body decomposed by fire; since it will afterwards appear that earth, though in its own nature fixed, may be rendered volatile by being intimately united with other substances which are so; and that, in fact, it is common enough for part of the earth of a body to be thus volatilized by its other principles: the second is, that what remains after the calcination of a body is not generally its earth in perfect purity, but combined with some of its other principles, which, though volatile in their own natures, have been fixed by the union contracted between it and them. We shall, in the sequel, produce some examples to illustrate this theory.

Earth therefore, properly so called, is a fixed principle, which is permanent in the fire. There is reason to think it very difficult if not impossible, to obtain the earthy principle entirely free from every other substance: for after our utmost endeavours to purify them, the earths we obtain from different compounds are found to have different properties, according to the different bodies from which they are procured; or else, if those earths be pure, we must allow them to be essentially different, seeing they have different properties.

Earth, in general, with regard to its properties, may be distributed into *fusible*, and *unfusible*; that is, into earth that is capable of melting or becoming fluid in the fire, and earth that constantly remains in a solid form, never melting in the strongest degree of heat to which we can expose it.

The former is also called *vitriifiable*, and the second *unvitriifiable* earth; because, when earth is melted by the force of fire, it becomes what we call *glass*, which is nothing but the parts of earth brought

brought into nearer contact, and more closely united by the means of fusion. Perhaps the earth, which we look upon as incapable of vitrification, might be fused if we could apply to it a sufficient degree of heat. It is at least certain that some earths, or stones, which separately resist the force of fire so that they cannot be melted, become fusible when mixed together. Experience convinced Mr. du Hamel that lime-stone and slate are of this kind. It is however undoubtedly true that one earth differs from another in its degree of fusibility: and this gives ground to believe, that there may be a species of earth absolutely unvitriifiable in its nature, which, being mixed in different proportions with fusible earths, renders them difficult to melt.

Whatever may be in this, as there are earths which we are absolutely unable to vitrify, that is a sufficient reason for our division of them. Unvitriifiable earths seem to be porous, for they imbibe water; whence they have also got the name of *Absorbent Earths*.

§. IV. Of FIRE.

The matter of the sun, or of light, the Phlogiston, fire, the sulphureous principle, the inflammable matter, are all of them names by which the element of fire is usually denoted. But it should seem, that an accurate distinction hath not yet been made between the different states in which it exists; that is, between the phenomena of fire actually existing as a principle in the composition of bodies, and those which it exhibits when existing separately and in its natural state: nor have proper distinct appellations been assigned to it in those different circumstances. In the latter state we may properly give it the names of fire, matter of the sun, of light, and of heat; and may consider it as a substance

stance composed of infinitely small particles, continually agitated by a most rapid motion, and of consequence, essentially fluid.

This substance, of which the sun may be called the general reservoir, seems to flow incessantly from that source, diffusing itself over the world, and through all the bodies we know; but not as a principle or essential part of them, since they may be deprived thereof, at least in a great measure, without suffering any decomposition. The greatest change produced on them, by its presence or its absence, is the rendering them fluid or solid: so that all other bodies may be deemed naturally solid; fire alone essentially fluid, and the principle of fluidity in others. This being presupposed, air itself might become solid, if it could be entirely deprived of the fire it contains; as bodies of most difficult fusion become fluid, when penetrated by a sufficient quantity of the particles of fire.

One of the chief properties of this pure fire is to penetrate easily into all bodies, and to diffuse itself among them with a sort of uniformity and equality: for if a heated body be contiguous to a cold one, the former communicates to the latter all its excess of heat, cooling in exact proportion as the other warms, till both come to have the very same degree of heat. Heat, however, is naturally communicable soonest to the upper parts of a body; and consequently, when a body cools, the under parts become soonest cold. It hath been observed, for instance, that the lower extremity of a heated body, freely suspended in the air, grows cold sooner than the upper; and that when a bar of iron is red-hot at one end, and cold at the other, the cold end is much sooner heated by placing the bar so that the hot end may be undermost, than when that end is turned uppermost. The levity of the matter of fire, and the vicinity of the earth, may possibly be the causes of this phenomenon.

Another

Another property of fire is to dilate all bodies to which it penetrates. This hath already been shewn with regard to air and water; and it produces the same effect on earth.

Fire is the most powerful agent we can employ to decompose bodies; and the greatest degree of heat producible by man, is that excited by the rays of the sun, collected in the focus of a large burning-glass.

§. V. Of the PHLOGISTON.

From what hath been said concerning the nature of fire, it is evidently impossible for us to fix and confine it in any body. Yet the phenomena attending the combustion of inflammable bodies shew, that they really contain the matter of fire as a constituent principle. By what mechanism then is this fluid, which is so subtle, so active, so difficult to confine, so capable of penetrating into every other substance in nature; how comes it, I say, to be so fixed as to make a component part of the most solid bodies? It is no easy matter to give a satisfactory answer to this question. But, without pretending to guess the cause of the phenomenon, let us rest contented with the certainty of the fact, the knowledge of which will undoubtedly procure us considerable advantages. Let us therefore examine the properties of fire thus fixed and become a principle of bodies. To this substance, in order to distinguish it from pure and unfixed fire, the chymists have assigned the peculiar title of the *Phlogiston*, which is indeed no other than a Greek word for the inflammable matter: by which latter name, as well as by that of the sulphureous principle, it is also sometimes called. It differs from elementary fire in the following particulars. 1. When united to a body, it communicates to it neither heat nor light. 2. It produces

produces no change in its state, whether of solidity or fluidity : so that a solid body does not become fluid by the accession of the Phlogiston, and *vice versa* ; the solid bodies to which it is joined, being only rendered thereby more apt to be fused by the force of the culinary fire. 3. We can convey it from the body, with which it is joined, into another body, so that it shall enter into the composition thereof, and remain fixed in it.

On this occasion both these bodies, that which is deprived of the Phlogiston and that which receives it, undergo very considerable alterations : and it is this last circumstance, in particular, that obliges us to distinguish the Phlogiston from pure fire, and to consider it as the element of fire combined with other substance, which serves it as a basis for constituting a kind of secondary principle. For if there were no difference between them, we should be able to introduce and fix pure fire itself, wherever we can introduce and fix the Phlogiston : yet this is what we can by no means do, as will appear from experiments to be afterwards produced.

Hitherto chymists have never been able to obtain the Phlogiston quite pure, and free from every other substance ; for there are but two ways of separating it from a body of which it makes a part ; to wit, either by applying some other body with which it may unite the moment it quits the former ; or else by calcining and burning the compound from which you desire to sever it. In the former case it is evident that we do not get the Phlogiston by itself, because it only passes from one combination into another ; and in the latter, it is intirely dissipated in the decomposition, so that no part of it can possibly be secured.

The inflammability of a body is an infallible sign that it contains a Phlogiston ; but from a body's not being inflammable, it cannot be inferred that it contains none : for experiments have demonstrated

that

that certain metals abound with it, which yet are by no means inflammable.

We have now delivered what is most necessary to be known concerning the principles of bodies in general. They have many other qualities besides those above-mentioned; but we cannot properly take notice of them here, because they presuppose an acquaintance with some other things relating to bodies, of which we have hitherto said nothing; intending to treat of them in the sequel as occasion shall offer. We shall only observe in this place, that when animal and vegetable matters are burnt, in such a manner as to hinder them from flaming, some part of the Phlogiston contained in them unites intimately with their most fixed earthy parts, and with them forms a compound, that can be consumed only by making it red-hot in the open air, where it sparkles and wastes away, without emitting any flame. This compound is called a *Coal*. We shall enquire into the properties of this coal under the head of oils: At present it suffices that we know in general what it is, and that it readily communicates to other bodies the Phlogiston it contains.



CHAP II.

A general View of the Relations or Affinities between Bodies.

BEFORE we can reduce compound bodies to the first principles above pointed out, we obtain, by analysing them, certain substances which are indeed more simple than the bodies they helped to compose, yet are themselves composed of our primary principles. They are therefore at one and the

the same time both principles and compounds; for which reason we shall, as was before said, call them by the name of secondary principles. Saline and oily matters chiefly constitute this class. But before we enter upon an examination of their properties, it is fit we lay before the reader a general view of what chymists understand by the relations or affinities of bodies; because it is necessary to know these, in order to a distinct conception of the different combinations we are to treat of.

All the experiments hitherto made concur with daily observation, to prove that different bodies, whether principles or compounds, have such a mutual conformity, relation, affinity, or attraction, if you will call it so, as disposes some of them to join and unite together, while they are incapable of contracting any union with others. This effect, whatever be its cause, will enable us to account for, and connect together, all the phenomena that chymistry produces. The nature of this universal affection of matter is distinctly laid down in the following propositions.

First, If one substance hath any affinity or conformity with another, the two will unite together, and form one compound.

Secondly, It may be laid down as a general rule, that all similar substances have an affinity with each other, and are consequently disposed to unite; as water with water, earth with earth, &c.

Thirdly, Substances that unite together lose some of their separate properties; and the compounds resulting from their union partake of the properties of those substances which serve as their principles.

Fourthly, The simpler any substances are, the more perceptible and considerable are their affinities: Whence it follows, that the less bodies are compounded, the more difficult it is to analyse them;

them ; that is, to separate from each other the principles of which they consist.

Fifthly, If a body consist of two substances, and to this compound be presented a third substance that has no affinity at all with one of the two primary substances aforesaid, but has a greater affinity with the other than those two substances have with each other, there will ensue a decomposition, and a new union ; that is, the third substance will separate the two compounding substances from each other, coalesce with that which has an affinity with it, form therewith a new combination, and disengage the other, which will then be left at liberty, and such as it was before it had contracted any union.

Sixthly, It happens sometimes that when a third substance is presented to a body consisting of two substances, no decomposition follows ; but the two compounding substances, without quitting each other, unite with the substance presented to them, and form a combination of three principles : And this comes to pass when that third substance has an equal, or nearly equal, affinity with each of the compounding substances. The same thing may also happen even when the third substance hath no affinity but with one of the compounding substances only. To produce such an effect, it is sufficient that one of the two compounding substances have to the third body a relation equal, or nearly equal, to that which it has to the other compounding substance, with which it is already combined. Thence it follows, that two substances, which, when apart, from all others, are incapable of contracting any union, may be rendered capable of incorporating together in some measure, and becoming parts of the same compound, by combining with a third substance, with which each of them has an equal affinity.

Seventhly, A body which, of itself, cannot decompose a compound consisting of two substances because, as we just now said, they have a greater affinity with each other than it has with either of them, becomes nevertheless capable of separating the two by uniting with one of them, when it is itself combined with another body, having a degree of affinity with that one, sufficient to compensate its own want thereof. In that case there are two affinities, and thence ensues a double decomposition and a double combination.

These fundamental truths, from which we shall deduce an explanation of all the phenomena in chemistry, will be confirmed and illustrated by applying them, as we shall do, to the several cases, of which our design in this treatise obliges us to give a circumstantial account.



C H A P. III.

Of Saline Substances in general.

1. Of Acids.
2. Of Alkalis.
3. Of the Marine Acid.

IF a particle of water be intimately united with a particle of earth, the result will be a new compound, which, according to our third proposition of affinities, will partake of the properties of earth and of water; and this combination principally forms what is called a *saline substance*. Consequently every saline substance must have an affinity with earth and with water, and be capable of uniting with both or either of them, whether they be separate or mixed together: and accordingly this pro

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erty characterises all salts, or saline substances, in general.

Water being volatile and earth fixed, salts in general are less volatile than the former, and less fixed than the latter; that is, fire, which cannot volatilize and carry off pure earth, is capable of volatilizing and volatilizing a saline substance; but when this requires a greater degree of heat than is necessary for producing the same effects on pure water.

There are several sorts of salts, differing from one another, in respect either of the quantity, or the quality of the earth in their composition; or, chiefly, they differ on account of some additional principles, which not being combined with them in sufficient quantity to hinder their saline properties from appearing, permit them to retain the name of salts, though they render them very different from the simplest saline substances.

It is easy to infer, from what has been said of salts in general, that some of them must be more, some less, fixed or volatile than others, and some more, some less, disposed to unite with water, with earth, or with particular sorts of earth, according to the nature or the proportion of their principles.

Before we proceed further, it is proper just to mention the principal reasons, which induce us to think that every saline substance is actually a combination of earth and water, as we supposed at our entering on this subject. The first is, the conformity salts have with earth and water, or the properties they possess in common with both. Of these properties we shall treat fully, as occasion offers to consider them, in examining the several sorts of salts. The second is, that all salts may be actually resolved into earth and water by sundry processes; particularly by repeated dissolution in water, evaporation, desiccation, and calcination. Indeed the

chymists have not yet been able to procure a saline substance, by combining earth and water together. This favours a suspicion, that, besides these two, there is some other principle in the composition of salts, which escapes our researches, because we cannot preserve it when we decompose them; but it is sufficient to our purpose, that water and earth are demonstrably amongst the real principles of saline substances, and that no experiment hath ever shewn us any other.

§. I. Of ACIDS.

Of all saline substances, the simplest is that called an *acid*, on account of its taste; which is like that of verjuice, sorrel, vinegar, and other sour things, which for the same reason are also called acids. By this peculiar taste are acids chiefly known. They have moreover the property of turning all the blue and violet colours of vegetables red, which distinguishes them from all other salts.

The form, under which acids most commonly appear, is that of a transparent liquor; though solidity is rather their natural state. This is owing to their affinity with water; which is so great that when they contain but just as much of it as is necessary to constitute them salts, and consequently have a solid form, they rapidly unite therewith the moment they come into contact with it: and as the air is always loaded with moisture and aqueous vapours, its contact alone is sufficient to liquify them, because they unite with its humidity, imbibe it greedily, and by that means become fluid. We therefore say, they attract the moisture of the air. This change of a salt from a solid to a fluid state by the sole contact of the air, is also called *deliquium*, so that when a salt changes in this manner from solid into a fluid form, it is said to run *per deliquium*. Acids being the simplest species of saline bodies

es, their affinities with different substances are longer than those of any other sort of salt with the same substances; which is agreeable to our fourth proposition concerning affinities.

Acids in general have a great affinity with earths: that with which they most readily unite is the unvitrifiable earth to which we gave the name of absorbent earth. They seem not to act at all upon vitrifiable earths, such as sand, nor yet upon some other kinds of earth, at least while they are in their natural state. Yet the nature of these earths may in some measure be changed, by making them red-hot in the fire, and then quenching them suddenly in cold water: for by repeating this often they are brought nearer to the nature of absorbent earths, and rendered capable of uniting with acids.

When an acid liquor is mixed with an absorbent earth, for instance with chalk, these two substances instantly rush into union, with so much impetuosity, especially if the acid liquor be as much dephlegmated, or contain as little water, as may be, that a great ebullition is immediately produced, attended with considerable hissing, heat, and vapours, which rise the very instant of their conjunction.

From the combination of an acid with an absorbent earth there arises a new compound, which some chymists have called *sal falsum*; because the acid by uniting with the earth loses its sour taste, and acquires another not unlike that of the common sea-salt used in our kitchens; yet varying according to the different sorts of acids and earths combined together. The acid at the same time loses its property of turning vegetable blues and violet colours red.

If we enquire what is become of its propensity to unite with water, we shall find that the earth, which of itself is not soluble in water, hath by its union with the acid acquired a facility of dissolving therein; so that our *sal falsum* is soluble in water. But,

on the other hand, the acid hath, by its union with the earth, lost part of the affinity it had with water; so that if a *sal salsum* be dried, and freed of all superfluous humidity, it will remain in that dry solid form, instead of attracting the moisture of the air, and running *per deliquium*, as the acid would do if it were pure and unmixed with earth. However, this general rule admits of some exceptions; and we shall have occasion in another place to take notice of certain combinations of acids with earths, which still continue to attract the moisture of the air, though not so strongly as a pure acid.

Acids have likewise a great affinity with the Phlogiston. When we come to treat of each acid in particular, we shall examine the combinations of each with the Phlogiston: they differ so widely from one another, and many of them are so little known, that we cannot at present give any general idea of them.

§. II. Of ALKALIS.

Alkalis are saline combinations, in which there is a greater proportion of earth than in acids. The principal arguments that may be adduced to prove this fact are these: First, if they be treated in the manner proposed above for analysing saline substances, we obtain from them a much greater quantity of earth than we do from acids. Secondly, by combining certain acids with certain earths, we can produce Alkalis; or at least such saline compounds as greatly resemble them. Our third and last argument is drawn from the properties of those alkalis which, when pure and unadulterated with any other principle, have less affinity with water than acids have, and are also more fixed, resisting the utmost force of fire. On this account it is that they have obtained the title of *fixed*, as well as to distinguish them from another species of al-

kali,

alkali, to be considered hereafter, which is impure and volatile.

Though fixed alkalis, when dry, sustain the utmost violence of fire without flying off in vapours, it is remarkable that, being boiled with water in an open vessel, considerable quantities of them rise with the steam: an effect which must be attributed to the great affinity between these two substances, by means whereof water communicates some part of its volatility to the fixed salt.

Alkalis freed of their superfluous humidity by calcination, attract the moisture of the air, but not so strongly as acids: so that it is easier to procure and preserve them in a solid form.

They flow in the fire, and are then capable of uniting with vitrifiable earths, and of forming there-with true glass, which, however, will partake of their properties, if they be used in sufficient quantity.

As they melt more readily than vitrifiable earth, they facilitate its fusion; so that a weaker fire will reduce it to glass, when a fixed alkali is joined with it, than will melt it without that addition.

Alkalis are known by their taste, which is acrid and fiery; and by the properties they possess of turning certain vegetable blues and violet colours green; particularly syrop of violets.

Their affinity with acids is greater than that of absorbent earths; and hence it comes to pass that if an alkali be presented to a combination of an acid with an absorbent earth, the earth will be separated from the acid by the alkali, and a new union between the acid and the alkali will take place. This is both an instance and a proof of our fifth proposition concerning affinities.

If a pure alkali be presented to a pure acid, they rush together with violence, and produce the same phenomena as were observed in the union of an absorbent

absorbent earth with an acid ; but in a greater and more remarkable degree.

Fixed alkalis may in general be divided into two sorts : one of these hath all the above recited properties ; but the other possesses some that are peculiar to itself. We shall consider this latter sort more particularly under the head of sea-salt.

§. III. Of NEUTRAL SALTS.

The acid and the alkali thus uniting mutually rob each other of their characteristic properties ; so that the compound resulting from their union produces no change in the blue colours of vegetables, and has a taste which is neither sour nor acrid, but saltish. A saline combination of this kind is for that reason named *sal falsum*, *sal medium*, or a *neutral salt*. Such combinations are also called by the plain general name of *salts*.

It must be observed that, in order to make these salts perfectly neutral, it is necessary that neither of the two saline principles of which they are compounded be predominant over the other ; for in that case they will have the properties of the prevailing principle. The reason is this : neither of these saline substances can unite with the other but in a limited proportion, beyond which there can be no further coalition between them. The action by which this perfect union is accomplished is termed *saturation* ; and the instant when such proportions of the two saline substances are mixed together, that the one is incorporated with as much of the other as it can possibly take up, is called the *point of saturation*. All this is equally applicable to the combination of an acid with an absorbent earth.

The combination is known to be perfect, that is, the point of saturation is known to be obtained, when after repeated affusions of an acid in small quantities

quantities to an alkali, or an absorbent earth, we find those phenomena cease, which in such cases constantly attend the conflict of union, as we said above, namely, ebullition, hissing, &c. and we may be assured the saturation is complete when the new compound hath neither an acid nor an acrid taste, nor in the least changes the blue colours of vegetables.

Neutral salts have not so great an affinity with water as either acids or alkalis have; because they are more compounded: for we observed before, that the affinities of the most compounded bodies are generally weaker than those of the most simple. In consequence hereof few neutral salts, when dried, attract the moisture of the air; and those that do, attract it more slowly, and in less quantity than either acids or alkalis do.

All neutral salts are soluble in water; but more or less readily, and in a greater or smaller quantity, according to the nature of their component principles.

Water made boiling hot dissolves a greater quantity of those salts which do not attract the moisture of the air, than when it is cold; and indeed it must be boiling hot to take up as much of them as it is capable of dissolving: but as for those which run in the air, the difference, if there be any, is imperceptible.

Some neutral salts have the property of shooting into crystals, and others have it not.

The nature of crystallization is this: Water cannot dissolve, nor keep in solution, more than a determinate quantity of any particular salt: when therefore such a quantity of water is evaporated from the solution of a salt capable of crystallization, that the remainder contains just as much salt as it can dissolve, then by continuing the evaporation, the salt gradually recovers its solid form, and concretes into several little transparent masses called

ed Crystals. These crystals have regular figures, all differing from one another according to the species of salt of which they are formed. Different methods of evaporating saline solutions have different effects on the figure and regularity of the crystals; and each particular sort of salt requires a peculiar method of evaporation to make its crystals perfectly regular.

A solution of salt designed for crystallization is usually evaporated by means of fire to a pellicle; that is, till the salt begin to concrete; which is perceived by a kind of thin dark skin that gathers on the surface of the liquor, and is formed of the crystallized particles of salt. When this pellicle appears the solution is suffered to cool, and the crystals form therein faster or slower according to the sort of salt in hand. If the evaporation be carried on briskly to perfect dryness, no crystals will be formed, and only an irregular mass of salt will be obtained.

The reasons why no crystals appear when the evaporation is hastily performed, and carried on to dryness, are, first, that the particles of salt, being always in motion while the solution is hot, have not time to exert their mutual affinities, and to unite together as crystallization requires: secondly, that a certain quantity of water enters into the very composition of crystals; which is therefore absolutely necessary to their formation, and in a greater or smaller proportion according to the nature of the salt*.

If these crystallized salts be exposed to the fire, they first part with that moisture which is not necessary to a saline concretion, and which they re-

* Those who have the curiosity to see a more particular account of the Crystallization of neutral salts, may read Mr. Rouelle's excellent memoir on that subject, among those of the academy of sciences for 1744.

ained only by means of their crystallization: afterwards they begin to flow, but with different degrees of fusibility.

It must be observed that certain salts melt as soon as they are exposed to the fire; namely, those which retain a great deal of water in crystallizing. But this fluor which they so readily acquire must be carefully distinguished from actual fusion: for it is owing only to their superfluous humidity, which heat renders capable of dissolving and liquifying them; so that when it is evaporated the salt ceases to be fluid, and requires a much greater degree of heat to bring it into real fusion.

The neutral salts that do not crystallize, may, indeed, be dried by evaporating the water which keeps them fluid; but by becoming solid they acquire no regular form; they again attract the moisture of the air, and are thereby melted into a liquor. These may be called *liquescent salts*.

Most of the neutral salts, that consist of an acid joined with a fixed alkali, or with an absorbent earth, are themselves fixed and resist the force of fire; yet several of them, if they be dissolved in water, and the solution boiled and evaporated, fly off along with the steams.

CHAP. IV.

Of the several sorts of saline substances.

1. Of the universal acid.
2. Of the nitrous acid
3. Of the marine acid.

§ I. *Of the UNIVERSAL ACID.*

THE universal acid is so called, because it is, in fact, the acid which is most universally diffused through all nature, in waters, in the atmosphere and in the bowels of the earth. But it is seldom pure; being almost always combined with some other substance. That from which we obtain it with most ease and in the greatest quantity, is vitriol, a mineral which we shall consider afterwards: and this is the reason why it is called the *vitriolic acid*, the name by which it is best known.

When the vitriolic acid contains but little phlegm, yet enough to give it a fluid form, it is called *Oil of vitriol*; on account of a certain unctuousity belonging to it. In truth this name is very improperly bestowed on it; for we shall afterwards see that, bating this unctuousness, it has none of the properties of oils. But this is not the only impropriety in names that we shall have occasion to censure.

If the vitriolic acid contain much water, it is then called *Spirit of vitriol*. When it does not contain enough to render it fluid, and so is in a solid form, it is named the *Icy oil of vitriol*.

When oil of vitriol highly concentrated is mixed with water, they rush into union with such impetuosity, that, the moment they touch each other

ere arises a hissing noise, like that of red-hot iron plunged in cold water; together with a very considerable degree of heat, proportioned to the degree which the acid was concentrated.

If instead of mixing this concentrated acid with water, you only leave it exposed to the air for some time, it attracts the moisture thereof, and imbibes most greedily. Both its bulk and its weight are increased by this accession; and if it be under any form, that is, if it be concreted, the phlegm thus acquired will soon resolve it into a fluid.

The addition of water renders the vitriolic acid, and indeed all other acids, weaker in one sense; which is, that when they are very aqueous they have on the tongue a much fainter taste of acidity, and are less active in the solution of some particular bodies: but that occasions no change in the strength of their affinities, but in some cases rather enables them to dissolve several substances, which, when well dephlegmated, they are not capable of attacking.

The vitriolic acid combined to the point of saturation with a particular absorbent earth, the nature of which is not yet well known, forms a neutral salt that crystallizes. This salt is called *Alum*, and the figure of its crystals is that of an octahedron, or solid of eight sides. These octahedra are angular pyramids, the angles of which are so cut off that four of the surfaces are hexagons, and the other four triangles.

There are several sorts of alum, which differ according to the earths combined with the vitriolic acid. Alum dissolves easily in water, and in crystallization retains a considerable quantity of it; which is the reason that being exposed to the fire it readily melts, swelling and puffing up as its superfluous moisture exhales. When that is quite evaporated, the remainder is called *Burnt Alum*, and is very difficult to fuse. The acid of the alum is

partly dissipated by this calcination. Its taste is saltish, with a degree of roughness and astringency.

The vitriolic acid combined with certain earths forms a kind of neutral salt called *Selenites*, which crystallizes in different forms according to the nature of its earth. There are numberless springs of water infected with dissolved selenites; but when this salt is once crystallized, it is exceeding difficult to dissolve it in water a second time. For that purpose a very great quantity of water is necessary, and moreover it must boil; for as it cools most of the dissolved selenites takes a solid form, and falls in a powder to the bottom of the vessel.

If an alkali be presented to the selenites, or to alum, these salts, according to the principles we have laid down, will be thereby decomposed; that is, the acid will quit the earths, and join the alkali, with which it hath a greater affinity. And from this conjunction of the vitriolic acid with a fixed alkali, there results another sort of neutral salt, which is called *Arcanum duplicatum*, *Sal duobus*, and *Vitriolated tartar*, because one of the fixed alkalis most in use is called salt of tartar.

Vitriolated tartar is almost as hard to dissolve in water as the selenites. It shoots into eight-sided crystals, having the apices of the pyramids pretty obtuse. Its taste is saltish, inclining to bitter; and it decrepitates on burning coals. It requires a very great degree of fire to make it flow.

The vitriolic acid is capable of uniting with the phlogiston, or rather it has a greater affinity with it than with any other body: whence it follows that all compounds, of which it makes a part, may be decomposed by means of the phlogiston.

From the conjunction of the vitriolic acid with the phlogiston, arises a compound called *Mineral Sulphur*, because it is found perfectly formed in the

bowel

flowers of the earth. It is also called *Sulphur vivum*, or simply, *sulphur*.

Sulphur is absolutely insoluble in water, and incapable of contracting any sort of union with it. It melts with a very moderate degree of heat, and sublimes in fine light downy tufts called *Flowers of sulphur*. By being thus sublimed it suffers no decomposition, let the operation be repeated ever so often; so that sublimed sulphur, or flower of sulphur, hath exactly the same properties as sulphur that has never been sublimed.

If sulphur be exposed to a brisk heat in the open air, it takes fire, burns, and is wholly consumed. This deflagration of sulphur is the only means we have of decomposing it, in order to obtain its acid in purity. The phlogiston is destroyed by the flame, and the acid exhales in vapours: these vapours collected have all the properties of the vitriolic acid, and differ from it only as they still retain some portion of the Phlogiston; which, however, soon quits them of its own accord, if the free access of the common air be not precluded.

The portion of Phlogiston retained by the acid of sulphur is much more considerable when that mineral is burnt gradually and slowly: in that case the vapours which rise from it have such a penetrating odour, that they instantaneously suffocate any person who draws in a certain quantity of them with his breath. These vapours constitute what is called the *volatile spirit of sulphur*. There is reason to think this portion of phlogiston which the acid retains, is combined therewith in a manner different from that in which these two are united in the sulphur itself; for, as has just been observed, nothing but actual burning is capable of separating the vitriolic acid and the phlogiston, which by their union form sulphur; whereas in the volatile spirit of sulphur they separate spontaneously when exposed to the open air; that is, the phlogiston flies off and

leaves the acid, which then becomes in every respect similar to the vitriolic acid.

That the volatile spirit of sulphur is a compound, as we have asserted it to be, appears evidently from hence, that whenever the vitriolic acid touches any substance containing the phlogiston provided that Phlogiston be disengaged or opened to a certain degree, a volatile spirit of sulphur is infallibly and immediately generated. This spirit hath all the properties of acids, but considerably weakened and of course less perceptible. It unites with absorbent earths or fixed alkalis; and with them forms neutral salts: but when combined therewith it may be separated from thence by the vitriolic acid and indeed by any of the mineral acids, because its affinities are weaker. Sulphur hath the property of uniting with absorbent earths, but not near so intimately as with fixed alkalis.

If equal parts of sulphur and an alkali be melted together, they incorporate with each other; and from their conjunction proceeds a compound of a most unpleasant smell, much like that of rotten eggs, and of a red colour nearly resembling that of an animal liver, which has occasioned it to bear the name of *Hepar sulphuris*, or *liver of sulphur*.

In this composition the fixed alkali communicates to the sulphur the property of dissolving in water: and hence it comes that liver of sulphur may be made as well when the alkali is dissolved by water into a fluid, as when it is fused by the action of fire.

Sulphur has less affinity than any acid with the fixed alkalis: and therefore liver of sulphur may be decomposed by any acid whatever; which will unite with the fixed alkali, form therewith a neutral salt, and separate the sulphur.

If liver of sulphur be dissolved in water, and an acid poured thereon, the liquor, which was transparent before, instantly turns to an opaque white; because

cause the sulphur, being forced to quit its union with the alkali, loses at the same time the property of dissolving in water, and appears again in its own unique form. The liquor thus made white by the sulphur is called *Milk of sulphur*.

If this liquor be suffered to stand still for some time, the particles of sulphur, now most minutely divided, gradually approach each other, unite, and sink insensibly to the bottom of the vessel; and then the liquor recovers its transparency. The sulphur thus deposited on the bottom of the vessel is called the *Magistery* or *Precipitate of sulphur*. The names *Magistery* and *Precipitate* are also given to all substances whatever that are separated from another by this method; which is the reason that we use the expression of precipitating one substance by another, to signify the separating one of them by means of the other.

§. II. Of the NITROUS ACID.

It is not certainly known what constitutes the difference between the nitrous acid and the vitriolic acid, with regard to the constituent principles of each. The most probable opinion is, that the nitrous acid is no other than the vitriolic acid combined with a certain quantity of phlogiston by the means of putrefaction. If it be so, the phlogiston must be united with the universal acid in another manner than it is in sulphur, and in its volatile spirit: for the nitrous acid differs from them both in its properties. What gives ground for this opinion is, that the nitrous acid is never found but in earths and stones which have been impregnated with matters subject to putrefaction, and which therefore must contain the phlogiston. For it is necessary just to observe here, though it be not yet proper to enter particularly into the subject, that

all substances susceptible of putrefaction really contain the Phlogiston.

The nitrous acid combined with certain absorbent earths, such as chalk, marble, boles, forms neutral salts which do not crystallize; and which after being dried, run in the air *per deliquium*.

All those neutral salts which consist of the nitrous acid joined to an earth, may be decomposed by a fixed alkali, with which the acid unites; and deserts the earth; and from this union of the nitrous acid, with a fixed alkali, results a new neutral salt, which is called *Nitre*, or *Salt-petre*. This latter name signifies the *Salt of stone*; and in fact nitre is extracted from the stones and plaister in which it forms, by boiling them in water saturated with a fixed alkali.

Nitre shoots in long crystals adhering sideways to each other; it has a saltish taste, which produces a sensation of cold on the tongue.

This salt easily dissolves in water; which, when boiling hot, takes up still a greater quantity thereof.

It flows with a pretty moderate degree of heat and continues fixed therein: but being purged by a brisk fire, and in the open air, it lets go some part of its acid, and indeed flies off itself in part.

The most remarkable property of nitre, and that which characterizes it, is its fulmination or explosion; the nature of which is as follows:

When nitre touches any substance containing a Phlogiston, and actually ignited, that is, actually on fire, it bursts out into a flame, burns, and is decomposed with much noise.

In this deflagration the acid is dissipated, and totally separated from the alkali, which now remains by itself.

Indeed the acid, at least the greatest part of it, is by this means quite destroyed. The alkali which is left when nitre is decomposed by deflagration,

is called in general *Fixed Nitre*, and, more particularly, nitre fixed by such and such a substance as was used in the operation. But if nitre be deflagrated with an inflammable substance containing the vitriolic acid, as sulphur, for instance, the fixed salt produced by the deflagration is not a pure alkali, but retains a good deal of the vitriolic acid, and, by combining therewith, hath now formed a neutral salt.

Hitherto chymists have been at a loss for the reason why nitre flames, and is decomposed in the manner above mentioned, when it comes in contact with a Phlogiston properly circumstanced. For my part, I conjecture it to be for the same reason that vitriolated tartar is also decomposed by the addition of a Phlogiston; viz. the nitrous acid, having a greater affinity with the Phlogiston than with the fixed alkali, naturally quits the latter to join with the former, and so produces a kind of sulphur, differing probably from the common sulphur, formed by the vitriolic acid, in that it is combustible to such a degree, as to take fire, and be consumed in the very moment of its production; so that it is impossible to prevent its being thus destroyed, and consequently impossible to save it. In support of this opinion, let it be considered, that the concurrence of the Phlogiston is absolutely necessary to produce this deflagration, and that the matter of pure fire is altogether incapable of effecting it; for, though nitre be exposed to the most violent degree of fire, even that in the focus of the most powerful burning-glass, it will not flame; nor will that effect ever happen till the nitre be brought into contact with a Phlogiston properly so called, that is, the matter of fire existing as a principle of some body; and it is moreover necessary that this phlogiston be actually on fire, and agitated with the igneous motion, or else that the nitre itself be red-

red-hot, and so penetrated with fire as to kindle any inflammable matter that touches it.

This experiment, among others, helps to shew the distinction that ought to be made between pure elementary fire, and fire become a principle of bodies, to which we have given the name of Phlogiston.

Before we leave this subject, we shall observe that nitre deflagrates only with such substances as contain the Phlogiston in its simplest and purest form; such as charcoal, sulphur, and the metal-line substances; and that, though it will not deflagrate without the addition of some combustible matter, it is nevertheless the only known body that will burn, and make other combustibles burn with it, in close vessels, without the admission of fresh air.

The nitrous acid hath not so great an affinity with earths and alkalis as the vitriolic acid hath with the same substances; whence it follows that the vitriolic acid decomposes all neutral salts arising from a combination of the nitrous acid with an earth or an alkali. The vitriolic acid expells the nitrous acid, unites with the substance which served it for a basis, and therewith forms a neutral salt, which is an alum, a selenites, or a vitriolated tartar, according to the nature of that basis.

The nitrous acid, when thus separated from its basis by the vitriolic acid, is named *Spirit of Nitre*, or *Aqua fortis*. If it be dephlegmated, or contain but little superfluous water, it exhales in reddish vapours; these vapours, being condensed and collected, form a liquor of a brownish yellow, that incessantly emits vapours of the same colour, and of a pungent disagreeable smell. These characters have procured it the names of *Smoking Spirit of Nitre*, and *Yellow Aqua Fortis*. This property in the nitrous acid, of exhaling in vapours, shews it to be less fixed than the vitriolic acid; for the latter

er, though ever so thoroughly dephlegmated, never yields any vapours, nor has it any smell.

§. III. *Of the ACID OF SEA-SALT.*

The acid of sea-salt is so called because it is in fact obtained from such sea-salt as is used in our kitchens. It is not certainly known in what this acid differs from the vitriolic and the nitrous, with regard to its constituent parts. Several of the ablest chymists, such as Becher and Stahl, are of opinion that the marine acid is no other than the universal acid united to a particular principle which they call a mercurial earth. Concerning this earth we shall have occasion to say more, when we come to treat of metallic substances: But in the mean time it must be owned, that the truth of this opinion is so far from being proved by a sufficient number of experiments, that the very existence of such a mercurial earth is not yet well established; and therefore, that we may not exceed the bounds of our knowledge, we shall content ourselves with delivering here the properties which characterize the acid in question, and by which it is distinguished from the two others considered above.

When it is combined with absorbent earths, such as lime and chalk, it forms a neutral salt that does not crystalize, and, when dried, attracts the moisture of the air. If the absorbent earth be not fully saturated with the marine acid, the salt thereby formed has the properties of a fixed alkali: and this is what made us say, when we were on the subject of those salts, that they might be imitated by combining an earth with an acid. The marine acid, like the rest, hath not so great an affinity with earths as with fixed alkalis.

When it is combined with the latter, it forms a neutral salt which shoots into cubical crystals. This salt is inclined to grow moist in the air, and is consequently

requently one of those which water dissolves in equal quantities, at least as to sense, whether it be boiling hot or quite cold.

The affinity of this acid with alkalis and absorbent earths is not so great as that of the vitriolic and nitrous acids with the same substances: whence it follows that, when combined therewith, it may be separated from them by either of those acids.

The acid of sea-salt, thus disengaged from the substance which served it for a basis, is called *Spirit of salt*. When it contains but little phlegm it is of a lemon colour, and continually emits many white, very dense, and very elastic vapours; of which account it is named the *smoking spirit of salt*. Its smell is not disagreeable, nor much unlike that of saffron; but extremely quick and suffocating when it smokes.

The acid of sea-salt, like the other two, seems to have a greater affinity with the Phlogiston, than with fixed alkalis. We are led to this opinion by a very curious operation, which gives ground to think that sea-salt may be decomposed by the proper application of a substance containing the Phlogiston.

From the marine acid combined with a Phlogiston results a kind of sulphur, differing from the common sort in many respects; but particularly in this property, that it takes fire of itself upon being exposed to the open air. This combination is called *English Phosphorus*, *Phosphorus of Urine*, because it is generally prepared from urine; or, only *Phosphorus*.

This combination of the marine acid with a Phlogiston is not easily effected; because it requires a difficult operation in appropriated vessels. For these reasons it does not always succeed; and phosphorus is so scarce and dear, that hitherto chymists have not been able to make on it the experiments necessary to discover all its properties. If phosphorus

be suffered to burn away in the air; a small quantity of an acid liquor may be obtained from it, which seems to be spirit of salt, but either altered, combined with some adventitious matter; for it has several properties that are not to be found in the pure marine acid; such as, leaving a fixed fusible substance behind it when exposed to a strong fire, and being easily combined with the Phlogiston so as to reproduce a phosphorus.

Phosphorus resembles sulphur in several of its properties; it is soluble in oils; it melts with a gentle heat: it is very combustible; it burns without producing foot; and its flame is vivid and white.

From what has been said of the union of the acid of sea-salt with a fixed alkali, and of the neutral salt resulting therefrom, it may be concluded that this neutral salt is no other than the common kitchen-salt. But it must be observed that the fixed alkali, which is the natural basis of the common salt obtained from sea-water, is of a sort somewhat differing from fixed alkalis in general, and hath certain properties peculiar to itself. For,

1. The basis of sea-salt differs from other fixed alkalis in this, that it crystallizes like a neutral salt.

2. It does not grow moist in the air: on the contrary, when exposed to the air, it loses part of the water that united with it in crystallization, by which means its crystals lose their transparency, become, as it were, mealy, and fall into a fine flour.

3. When combined with the vitriolitic acid to the point of saturation, it forms a neutral salt differing from vitriolated tartar, first, in the figure of its crystals, which are oblong six-sided solids; secondly, in its quantity of water, which in crystallization unites therewith in a much greater proportion than with vitriolated tartar; whence it follows, that this salt dissolves in water more readily than vitriolated tartar; thirdly, in that it flows with a very

very moderate degree of heat, whereas vitriolated tartar requires a very fierce one.

If the acid of sea-salt be separated from its basis by means of the vitriolic acid, it is easy to see that, when the operation is finished, the salt we have been speaking of must be the result. A famous chymist, named Glauber, was the first who extracted the spirit of salt in this manner, examined the neutral salt resulting from his process, and finding it to have some singular properties, called it his *Sal mirabile*, or wonderful salt: On this account it is still called Glauber's *sal mirabile*, or plainly *Glauber's salt*.

4. When the basis of sea-salt is combined with the nitrous acid to the point of saturation, there results a neutral salt, or a sort of nitre, differing from the common nitre, first, in that it attracts the moisture of the air pretty strongly; and this makes it difficult to crystallize: Secondly, in the figure of its crystals, which are parallelopipeds; and this has procured it the name of *Quadrangular Nitre*.

Common salt, or the neutral salt formed by combining the marine acid with this particular sort of fixed alkali, has a taste well known to every body. The figure of its crystals is exactly cubical. It grows moist in the air, and when exposed to the fire, it bursts, before it melts, into many little fragments, with a crackling noise; which is called the *Decrepitation* of sea-salt.

That neutral salt mentioned above, which is formed by combining the marine acid with a common fixed alkali, and called *Sal febrifugum Sylvii*, hath also this property.

India furnishes us with a saline substance, known by the name of *Borax*, which flows very easily, and then takes the form of glass. It is of great use in facilitating the fusion of metallic substances. It possesses some of the properties of fixed alkalis, which

which has induced certain chymists to represent it, through mistake as a pure fixed alkali.

By mixing borax with the vitriolic acid, Mr. Homberg obtained from it a salt, which sublimes in certain degree of heat, whenever such a mixture is made. This salt has very singular properties; but its nature is not yet thoroughly understood. It dissolves in water with great difficulty; it is not volatile, though it rises by sublimation from the borax. According to Mr. Rouelle's observation, it rises then only by means of the water which carries it up: For, when once made, it abides the fiercest fire, flows and vitrifies just as borax does; provided care be taken to free it previously from moisture, by drying it properly. Mr. Homberg called it *Sedative salt*, on account of its medical effects. The sedative salt hath the appearance, and some of the properties, of a neutral salt: for it shoots into crystals, and does not change the colour of violets: but it acts the part of an acid with regard to alkalis, uniting with them to the point of saturation, and thereby forming a true neutral salt. It also acts, like the acid of vitriol on all neutral salt: that is, it discharges the acid of such as have not the vitriolic acid in their composition.

Since Mr. Homberg's time it hath been discovered that a sedative salt may be made either with the nitrous or with the marine acid; and that sublimation is not necessary to extract it from the borax, but that it may be obtained by crystallization only. For this latter discovery we are indebted to Mr. Geoffrey, as we are to Mr. Lemery for the former.

Since that time M. Baron d'Henouville, an able chymist, hath shewn that a sedative salt may be obtained by the means of vegetable acids; and hath lately demonstrated, in some excellent papers published in the collection of memoirs written by the correspondents of the Academy of Sciences, that

the sedative salt exists actually and perfectly in the borax, and that it is not produced by mixing acids with that saline substance, as it seems all the chymists before him imagined. This he proves convincingly from his analysis of borax, (which thereby appears to be nothing else but the sedative salt united with that fixed alkali which is the basis of sea-salt) and from his regenerating the same borax by uniting together that alkali and the sedative salt: a proof the most complete that can possibly be produced in natural philosophy, and equivalent to demonstration itself.

In order to finish what remains to be said upon the several sorts of saline substances, we should now speak of the acids obtained from vegetables and animals, and also of the volatile alkalis: but, seeing these saline substances differ from those of which we have already treated, only as they are variously altered by the unions they have contracted with certain principles of vegetables and animals, of which nothing has been yet said, it is proper to defer being particular concerning them, till we have explained those principles.



C H A P. V.

Of L I M E.

AN Y substance whatever, that has been roasted a considerable time in a strong fire without melting, is commonly called a *Calx*. Stones and metals are the principal subjects that have the property of being converted into *Calces*. We shall treat of Metalline *Calces* in a subsequent chapter.

and in this confine ourselves to the *calx* of *stone*, known by the name of *lime*.

In treating of earths in general we observed that they may be divided into two principal kinds; one of which actually and properly flows when exposed to the action of fire, and turns to glass; whence it is called a *fusible* or *vitriifiable* earth; the other resists the utmost force of fire, and is therefore said to be an *unfusible* or *unvitriifiable* earth. The latter is also not uncommonly called *calcinable* earth; though fundry sorts of unfusible earths are incapable of acquiring by the action of fire all the qualities of *calcined* earth, or *lime* properly so called: such earths are particularly distinguished by the denomination of *refractory* earths.

As the different sorts of stones are nothing more than compounds of different earths, they have the same properties with the earths of which they are composed, and may, like them, be divided into fusible or vitriifiable, and unfusible or calcinable. The fusible stones are generally denoted by the name of *flints*; the calcinable stones, again, are the several sorts of marbles, cretaceous stones, those commonly called free-stones, &c. some of which, as they make the best lime, are, by way of eminence, called *lime-stones*. Sea-shells also, and stones that abound with fossile shells, are capable of being burnt to lime.

All these substances, being exposed, for a longer or shorter time, as the nature of each requires, to the violent action of fire, are said to be *calcined*. By calcination they lose a considerable part of their weight, acquire a white colour, and become friable though ever so solid before; as, for instance, the very hardest marbles. These substances, when thus calcined, take the name of *quick lime*.

Water penetrates quick lime, and rushes into it with vast activity. If a lump of newly calcined lime be thrown into water, it instantly excites al-

most as great a noise, ebullition, and smoke, as would be produced by a piece of red-hot iron; with such a degree of heat too, that, if the lime be in due proportion to the water, it will set fire to combustible bodies; as hath unfortunately happened to vessels laden with quick lime, on their springing a small leak.

As soon as quick lime is put into water, it swells, and falls asunder into an infinite number of minute particles: in a word, it is in a manner dissolved by the water, which forms therewith a sort of white paste called *slacked lime*.

If the quantity of water be considerable enough for the lime to form with it a white liquor, this liquor is called *lac calcis*; which, being left some time to settle, grows clear and transparent, the lime which was suspended therein, and occasioned its opacity, subsiding to the bottom of the vessel. Then there forms on the surface of the liquor a crystalline pellicle, somewhat opaque and dark coloured, which being skimmed off is reproduced from time to time. This matter is called *cremor calcis*.

Slacked lime gradually grows dry, and takes the form of a solid body, but full of cracks and destitute of firmness. The event is different when you mix it up, while yet a paste, with a certain quantity of uncalcined stony matter, such as sand for example: then it takes the name of *mortar*, and gradually acquires, as it grows drier and older, a hardness equal to that of the best stones. This is a very singular property of lime, nor is it easy to account for it: but it is a beneficial one; for every body knows the use of mortar in building.

Quick lime attracts the moisture of the air, in the same manner as concentrated acids, and dry fixed alkalis; but not in such quantities as to render it fluid: it only falls into extremely small particles,

cles, takes the form of a fine powder, and the title of *lime slacked in the air*.

Lime once slacked, however dry it may afterwards appear, always retains a large portion of the water it had imbibed; which cannot be separated from it again but by means of a violent calcination. Being so recalcined it returns to be quick lime, recovering all its properties.

Besides this great affinity of quick lime with water, which discovers a saline character, it has several other saline properties, to be afterwards examined, much resembling those of fixed alkalis. In chymistry it acts very nearly as those salts do, and may be considered as holding the middle rank between a pure absorbent earth and a fixed alkali: and this hath induced many chymists to think that lime contains a true salt, to which all the properties it possesses in common with salts may be attributed.

But as the chymical examination of this subject hath long been neglected, the existence of a saline substance in lime hath been long doubtful. Mr. du Fay, author of some excellent chymical experiments, was one of the first who obtained a salt from lime, by lixiviating it with a great deal of water, which he afterwards evaporated. But the quantity of salt he obtained by that means was very small; nor was it of an alkaline nature, as one would think it should have been, considering the properties of lime. Mr. du Fay did not carry his experiments on this subject any farther, probably for want of time; nor did he determine of what nature the salt was.

Mr. Malouin had the curiosity to examine this salt of lime, and soon found that it was nothing else but what was above called *cremor calcis*. He found moreover, that, by mixing a fixed alkali with lime-water, a vitriolated tartar was formed; that, by mixing therewith an alkali like the basis of sea salt,

salt, a Glauber's salt was produced; and lastly, by combining lime with a substance abounding in phlogiston he obtained a true sulphur. These very ingenious experiments prove to a demonstration that the vitriolic acid constitutes the salt of lime: for, as hath been shewn, no other acid is capable of forming such combinations. On the other hand, Mr. Malouin, having forced the vitriolic acid on this salt to combine with a phlogiston, found its basis to be earthy, and analagous to that of the selenites: whence he concluded, that the salt of lime is a true neutral salt of the same kind as the selenites. Mr Malouin tells us he found several other salts in lime. But as none of them was a fixed alkali, and as all the saline properties of lime have an affinity with those of that kind of salt, there is great reason to think that all those salts are foreign to lime, and that their union with it is merely accidental.

I myself have made several experiments in order to get some insight into the saline nature of lime, and shall here produce the result with all possible conciseness. I took several stones of different kinds, some of which produced by calcination a very strong lime, and others but a very weak one. These I impregnated with different saline substances, acids, alkalis, and neutrals, and then exposed them all to the same degree of fire, which was a pretty strong one, and long enough continued to have made very good lime of stones the most difficult to calcine. The consequence was, that, in the first place, those stones which naturally made but a weak lime were not by this process converted into a stronger lime; and, moreover, that none of these stones, even such as would naturally have produced the most active lime, had acquired the properties of lime. These experiments I varied many ways, employing different proportions of saline matters, and almost every possible degree of fire, and constantly observed, after calcination, that all those stones

stones were so much the further from the nature of lime, as they had been combined with larger doses of salts. Among those which were impregnated with the greatest proportion of salts, and had suffered the greatest violence of fire, I observed some that had begun to flow, and were in a manner vivified. Now, as the same subject cannot be, at one and the same time, in the state of glass and of lime; as a body cannot approach to one of these states but in proportion as it recedes from the other; and as salts in general dispose those bodies to fusion and vitrification which are in themselves the mostaverse to either, I concluded from my experiments, that the saline substances I used, had, by acting as fluxes upon the stones, prevented their calcination; that consequently we may suspect there is no saline matter in the composition of lime, as lime; and that lime does not owe its saline and alkaline properties to any salt; or at least that if it does owe those properties to a salt, such salt must be naturally and originally combined with the matter of the stone in so just a proportion, that it is impossible to increase the quantity thereof without prejudicing the lime, and depriving it in some measure of its virtue. This theory agrees perfectly with the illustrious Stahl's opinion; for he thinks, as we observed in discoursing of salts in general, that every saline substance is but an earth combined in a certain manner with water. This notion he applies to lime, and says that fire only subtilizes and attenuates the earthy matter, and thereby renders it capable of uniting with water in such a manner, that the result of their combination shall be a substance having saline properties; and that lime accordingly never acquires these properties till it be combined with water. I have dwelt longer on the salt of lime than I shall on any other particular; because the subject, though in itself of great importance, has hitherto been

been but little attended to, and because the experiments here recited are entirely new.

Lime unites with all acids, and in conjunction with them exhibits various phenomena.

The vitriolic acid poured upon lime dissolves it with effervescence and heat. From this mixture there exhales a great quantity of vapours, in smell and colour perfectly like those of sea-salt; from which however they are found to be very different when collected into a liquor. From this combination of the vitriolic acid with lime arises a neutral salt, which shoots into crystals, and is of the same kind with the selenitic salt obtained from lime by Mr. Malouin.

The nitrous acid poured upon lime dissolves it in like manner with effervescence and heat: but the solution is transparent, and therein differs from the former, which is opaque. From this mixture there arises a neutral salt, which does not crystallize, and has withal the very singular property of being volatile, and rising wholly by distillation in a liquid form. This phenomenon is so much the more remarkable, as lime, the basis of this salt, is one of the most fixed bodies known in chymistry.

With the acid of sea-salt lime forms also a singular sort of salt, which greedily imbibes the moisture of the air. We shall have occasion to take further notice of it in another place.

These experiments made on lime with acids are likewise quite new. We are indebted for them to Mr. du Hamel of the academy of sciences, whose admirable Memoirs on several subjects shew his extensive knowledge in all parts of natural philosophy.

Lime applied to fixed alkalis adds considerably to their caustic quality, and makes them more penetrating and active. An alkaline lixivium in which lime hath been boiled, being evaporated to dryness, forms a very caustic substance, which flows in the fire

re, much more easily, attracts and retains moisture much more strongly than fixed alkalis that have not been so treated. An alkali thus acuated by lime is called the *caustic stone*, or *potential caustic*; because it is employed by surgeons to produce chchars on the skin and cauterize it.

CHAPTER VI.

Of Metallic Substances in general.

METALLIC substances are heavy, glittering, opaque, fusible bodies. They consist chiefly of a vitrifiable earth united with the phlogiston.

Several chymists insist on a third principle in these bodies, and have given it the name of *Mercurial earth*; which, according to Becher and Stahl, is the very same that being combined with the vitriolic acid forms and characterizes the acid of sea-salt. The existence of this principle hath not yet been demonstrated by any decisive experiment; but we shall shew that there are pretty strong reasons for admitting it.

We shall begin with mentioning the experiments which prove metallic substances to consist of a vitrifiable earth united with the phlogiston. The first is this: if they be calcined in such a manner as to have no communication with any inflammable matter, they will be spoiled of all their properties, and reduced to an earth or calx, that has neither the splendour nor the ductility of a metal, and in a strong fire turns to an actual glass, instead of flowing like a metal.

The second is, that the calx or the glass resulting from a metal thus decomposed, recovers all its crystalline properties by being fused in immediate contact

contact with an inflammable substance, capable of restoring the phlogiston of which calcination had deprived it.

On this occasion we must observe that chymists have not yet been able, by adding the phlogiston to give the proprieties of metals to all sorts of vitrifiable earths indiscriminately; but to such only as originally made a part of some metallic body. For example, a compound cannot be made with the phlogiston and sand that shall have the least resemblance of a metal: and this is what seems to point out the reality of a third principle, as necessary to form the metalline combination. This principle may probably remain united with the vitrifiable earth of a metallic substance, when reduced to a glass; whence it follows, that such vitrified metals require only the addition of a phlogiston to enable them to appear again in their pristine form.

It may be inferred from another experiment, that the calx and the glass of a metal are not its pure vitrifiable earth, properly so called: for by repeated or long continued calcinations, such a calx or glass may be rendered incapable of ever resuming the metalline form, in whatever manner the phlogiston be afterwards applied to it; so that by this means it is brought into the condition of a pure vitrifiable earth, absolutely free from any mixture. Those chymists who patronise the mercurial earth, produce many other proofs of the existence of that principle in metallic substances; but they would be misplaced in an elementary treatise like this.

When by adding the phlogiston to a metallic glass we restore it to the form of a metal, we are said to *reduce, resuscitate, or revivify* that metal.

Metallic substances are of different kinds, and are divided into *Metals* and *Semi-metals*.

Those are called metals which besides their metalline splendor and appearance, are also malleable; that is, have the property of stretching under the hammer.

hammer, and by that means of being wrought into different forms without breaking.

Those which have only the metalline splendour and appearance, without malleability, are called *semi-metals*.

Metals are also further subdivided into two sorts; *viz. perfect and imperfect metals*.

The perfect metals are those which suffer no damage or change whatever by the most violent and most lasting action of fire.

The imperfect metals are those which by the force of fire may be deprived of their phlogiston, and consequently of their metalline form.

When but a moderate degree of fire is employed to deprive a metal of its phlogiston, the metal is said to be *calcined*; and then it appears in the form of a powdered earth, which is called a *Calx*: and this metalline calx being exposed to a more violent degree of fire melts and turns to glass.

Metallic substances have an affinity with acids: but not equally with all; that is, every metallic substance is not capable of uniting and joining with every acid.

When an acid unites with a metallic substance there commonly arises an ebullition, attended with a kind of hissing noise and fuming exhalations. By degrees, as the union becomes more perfect, the particles of the metal combining with the acid become invisible: this is termed *Dissolution*; and when the metalline mass thus disappears in an acid, the metal is said to be *dissolved* by that acid. It is proper to observe that acids act upon metalline substances, in one respect, just as they do upon alkalis and absorbent earths: for an acid cannot take up above such a certain proportion thereof as is sufficient to saturate it, to destroy several of its properties, and weaken others. For example, when an acid is combined with a metal to the point of saturation, it loses its taste, does not turn the blue colour

colour of a vegetable red, and its affinity with water is considerably impaired. On the other hand metalline substances, which when pure are incapable of uniting with water, by being joined with an acid acquire the property of dissolving in water. These combinations of metalline substances with acids form different sorts of neutral salts; some of which have the property of shooting into crystals while others have it not: most of them, when thoroughly dried, attract the moisture of the air.

The affinity which metalline substances have with acids is less than that which absorbent earths and fixed alkalis have with the same acids: so that all metalline salts may be decomposed by one of these substances, which will unite with the acid and precipitate the metal.

Metalline substances thus separated from an acid solvent are called *Magisteries*, and *Precipitates*, or metals. None of these precipitates, except those of the perfect metals, retain the metalline form: most of their phlogiston hath been destroyed by the solution and precipitation, and must be restored before they can recover their properties. In short they are nearly in the same state with metalline substances deprived of their phlogiston by calcination; and accordingly such a precipitate is called a *Calx*.

A metalline calx prepared in this manner loses a greater or a less portion of its phlogiston, the more or less effectually and thoroughly the metalline substance, of which it made a part, was dissolved by the acid.

Metallic substances have affinities with each other which differ according to their different kinds: but this is not universal; for some of them are incapable of any sort of union with some others.

It must be observed that metallic substances will not unite, except they be both in a similar state; that is, both in a metalline form, or both in a

form of a glass; for a metalline substance retaining phlogiston cannot contract an union with any metallic glass, even its own.



C H A P. VII.

Of Metals.

Of gold. 2. Of silver. 3. Of copper. 4. Of
iron. 5. Of tin. 6. Of lead.

Here are six metals, of which two are perfect and four imperfect. The perfect metals are gold and silver; the others are copper, tin, lead, and iron. Some chymists admit a seventh metal, wit, quicksilver: but as it is not malleable, it has been generally considered as a metallic body of a particular kind. We shall soon have occasion to examine it more minutely.

The ancient chymists, or rather the alchymists, who fancied a certain relation or analogy between metals and the heavenly bodies, bestowed on the seven metals, reckoning quicksilver one of them, the names of the seven planets of the ancients, according to the affinity which they imagined they observed between those several bodies. Thus gold was called *Sol*, silver *Luna*, copper *Venus*, tin *Jupiter*, lead *Saturn*, iron *Mars*, and quicksilver *Mercury*. Though these names were assigned for reasons merely chimerical, yet they still keep their ground; so that it is not uncommon to find the metals called by the names, and denoted by the characters, of the planets, in the writings even of the best chymists. Metals are the heaviest bodies known in nature.

§. I. Of GOLD.

Gold is the heaviest of all metals. The arts of wire-drawing and gold-beating shew its wonderful ductility. The greatest violence of fire is not able to produce any alteration in it. Indeed Mr. Homberg, a famous chymist, pretended that he had made this metal fume, and even vitrified it, by exposing it to the focus of one of the best burning glasses, known by the name of the Lens of the *Palais royal*: but there are very good reasons for calling in question the experiments he made on this occasion, or rather for thinking that he was quite mistaken. For,

1. No man hath since been able to vitrify gold, though several good experimenters have assiduously tried to effect it, by exposing it to the focus of the same lens, and of other burning-glasses still stronger.

2. It hath been observed that though gold, when exposed to the focus of those glasses, did indeed emit some vapours and decrease in weight; yet those vapours being carefully collected on a piece of paper, proved to be true gold, in no degree vitrified and which consequently had suffered no change but that of being carried away by the violence of the heat, its nature not being in the least altered.

3. The small portion of vitrified matter, which was formed on the arm that supported the gold in Mr. Homberg's experiment, may have come either from the arm itself, or rather from some heterogeneous particles contained in the gold; for it is almost impossible to have it perfectly pure.

4. Neither Mr. Homberg, nor any that have repeated his experiment, ever reduced this pretended glass of gold by restoring its phlogiston, as is done with other metallic glasses.

5. To render the experiment decisive, the whole

mass of gold employed ought to have been vitrified; which was not the case.

Nevertheless I do not pretend that this metal is in its own nature absolutely indestructible, and unvitriifiable: but there is reason to think that no body hath hitherto found the means of producing those effects on it, probably for want of a sufficient degree of fire; at least the point is very doubtful.

Gold cannot be dissolved by any pure acid: but if the acid of nitre be mixed with the acid of sea-salt, there results a compound acid liquor, with which it has so great an affinity that it is capable of being perfectly dissolved thereby. The chymists have called this solvent *Aqua Regis*, on account of its being the only acid that can dissolve gold, which they consider as the king of metals. The solution of gold is of a beautiful orange-colour.

If gold dissolved in *aqua regis* be precipitated by an alkali or an absorbent earth, the precipitate gently dried, and then exposed to a certain degree of heat, is instantly dispersed into the air, with a most violent explosion and noise: Gold thus precipitated is therefore called *Aurum fulminans*. But if the precipitated gold be carefully washed in plenty of water, so as to clear it of all the adhering saline particles, it will not fulminate; but may be melted in a crucible without any additament, and will then appear in its usual form. The acid of vitriol being poured on *aurum fulminans* likewise deprives it of its fulminating quality.

Gold does not begin to flow till it be red-hot like live coal. Though it be the most malleable and most ductile of all metals, it has the singular property of losing its ductility more easily than any of them: even the fumes of charcoal are sufficient to deprive it thereof, if they come in contact with it while it is in fusion.

The malleability of this metal, and indeed of all

the rest, is also considerably diminished by exposing it suddenly to cold when it is red-hot; for example, by quenching it in water, or even barely exposing it to the cold air.

The way to restore ductility to gold, when lost by its coming in contact with the vapour of coals, and in general to any metal rendered less malleable by being suddenly cooled, is to heat it again, to keep it red hot a considerable time, and then to let it cool very slowly and gradually: this operation frequently repeated will by degrees much increase the malleability of a metal.

Pure sulphur hath no effect on gold; but being combined with an alkali into a *hepar sulphuris*, it unites therewith very readily. Nay, so intimate is their union, that the gold by means thereof becomes soluble in water; and this new compound of gold and liver of sulphur, being dissolved in water, will pass through the pores of brown paper without suffering any decomposition; which does not happen, at least in such a manifest degree, to other metallic substances dissolved by liver of sulphur.

Aurum fulminans mixed and melted with flower of sulphur loses its fulminating quality: which arises from hence, that on this occasion the sulphur burns, and its acid, which is the same with the vitriolic, being thereby set at liberty becomes capable of acting upon the gold as a vitriolic acid would; which, as was said above, deprives the gold of its fulminating quality.

§. II. Of SILVER.

Next to gold, silver is the most perfect metal. Like gold it resists the utmost violence of fire, even that in the focus of a burning-glass. However it holds only the second place among metals; because it is lighter than gold by almost one half; is also somewhat

somewhat less ductile ; and lastly, because it is acted upon by a greater number of solvents.

Yet silver hath one advantage over gold, namely that of being a little harder ; which makes it also more sonorous.

This metal, like gold, begins to flow when it is thoroughly penetrated by the fire as to appear united like a live coal.

While this metal is in fusion, the immediate contact of the vapour of burning coals deprives it almost entirely of its malleability, in the same manner as we observed happens to gold ; but both these metals easily recover that property by being melted with nitre.

The nitrous acid is the true solvent of silver, and being somewhat dephlegmated will very readily and easily take up a quantity of silver equal in weight to itself.

Silver thus combined with the nitrous acid forms a metallic salt which shoots into crystals, called by the name of *lunar crystals*, or *crystals of silver*.

These crystals are most violently caustic : applied to the skin they quickly affect it much as a live coal would ; they produce a blackish eschar, corroding and entirely destroying the parts they touch. Surgeons use them to eat away the proud fungous flesh of ulcers. As silver united with the nitrous acid hath the property of blackening all animal substances, a solution of this metallic salt is employed to dye hair, or other animal matters, of a beautiful and durable black.

These crystals flow with a very moderate heat, and even before they grow red. Being thus melted they form a blackish mass ; and in this form they are used by surgeons, under the title of *Lapis infernalis*, *infernal stone*, or *lunar caustic*.

Silver is also dissolved by the vitriolic acid : but when the acid must be concentrated, and in quantity double the weight of the silver ; nor will the solution

lution succeed without a considerable degree of heat.

Spirit of salt and *aqua regis*, as well as the other acids, are incapable of dissolving this metal; at least in the ordinary way.

Though silver be not soluble in the acid of sea-salt, nor easily in the acid of vitriol, as hath just been observed, it doth not follow that it hath but a weak affinity with the latter, and none at all with the former: on the contrary, it appears from experiment that it hath with these two acids a much greater affinity than with the acid of nitre: which is singular enough, considering the facility with which this last acid dissolves it.

The experiment which proves the fact, is this. To a solution of silver in the nitrous acid, add the acid either of vitriol or of sea-salt, and the silver will instantly quit its nitrous solvent to join with the superadded acid.

Silver thus united with the vitriolic or the marine acid is less soluble in water than when combined with the nitrous acid: and for this reason it is, that when either of these two acids is added to a solution of silver, the liquor immediately becomes white, and a precipitate is formed, which is no other than the silver united with the precipitating acid. If the precipitation be effected by the vitriolic acid, the precipitate will disappear upon adding a sufficient quantity of water, because there will then be water enough to dissolve it. But the case is not the same when the precipitation is made by the marine acid: for silver combined therewith is scarce soluble in water.

This precipitate of silver procured by means of the marine acid is very easily fused, and when fused, changes to a substance in some measure transparent and flexible; which hath occasioned it to be called by the name of *Luna Cornea*. If it be proposed to decompose this *luna cornea*, that is, to separate

separate the marine acid from the silver with which it is united, the *luna cornea* must be melted along with fatty and absorbent matters, with which the acid will unite, and leave the metal exceeding pure.

It must be observed, that if, instead of the marine acid, sea-salt in substance be added to a solution of silver in the nitrous acid, a Precipitate is also produced, which by fusion appears to be a true *luna cornea*. The reason is, that the sea-salt is decomposed by the nitrous acid, which seizes its basis, as having a greater affinity therewith than its own acid hath; and this acid being consequently disengaged and set at liberty unites with the silver, which, as has been shewn, has a greater affinity with it than with the nitrous acid. This is an instance of decomposition effected by means of one of those double affinities mentioned by us in our seventh proposition concerning affinities.

From what hath been already said it is clear, that all these combinations of silver with acids may be decomposed by absorbent earths and by fixed alkalis; it being a general law with regard to all metallic substances. We shall not therefore repeat this observation when we come to treat of the other metals; unless some particular occasion require it.

With regard to silver I must take notice that, when separated by these means from the acids in which it was dissolved, it requires nothing but simple fusion to restore it to its usual form; because it does not, any more than gold, lose its Phlogiston by those solutions and precipitations.

Silver unites with sulphur in fusion. If this metal be only made red hot in a crucible, and sulphur be then added, it immediately flows; the sulphur acting as a flux to it. Silver thus united with sulphur forms a mass that may be cut, is half malleable, and hath nearly the colour and consistence of

of lead. If this sulphurated silver be kept a long time in fusion, and in a great degree of heat, the sulphur flies off and leaves the silver pure. But if the sulphur be evaporated by a violent heat, it carries off with it part of the silver.

Silver unites and mixes perfectly with gold in fusion. The two metals thus mixed form a compound with properties partaking of both.

Metallurgists have hitherto sought in vain for a perfectly good and easy method of separating these two metals by the *dry way* only: (this term is used to signify all operations performed by fusion:) but they are conveniently enough parted by the *moist way*, that is, by acid solvents. This method is founded on the above mentioned properties of gold and silver with respect to acids. It hath been shewn that *aqua regis* only will dissolve gold; that silver, on the contrary, is not soluble by *aqua regis*, and that its proper solvent is the acid of nitre; consequently, when gold and silver are mixed together, if the compound mass be put into *aqua fortis*, this acid will take up all the silver, without dissolving a particle of the gold, which will therefore remain pure; and by this means the desired separation is effected. This method, which is commonly made use of by goldsmiths and in mints, is called the *Parting Assay*.

It is plain that if *aqua regis* were employed instead of *aqua fortis*, the separation would be equally effected; and that the only difference between this process and the former would consist in this, that now the gold would be dissolved, and the silver remain pure. But the operation by *aqua fortis* is preferable; because *aqua regis* does take up a little silver, whereas *aqua fortis* hath not the least effect on gold.

It must be observed that when gold and silver are mixed together in equal parts they cannot be parted by the means of *aqua fortis*. To enable the

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aqua fortis to act duly on the silver, this metal must be, at least in a triple proportion to the gold. If it be in a less proportion, you must either employ *aqua regis* to make the separation, or, if you prefer the use of *aqua forti*, melt the metalline mass, and add as much silver as is necessary to make up the proportion above-mentioned: And hence this process is called *Quartation*.

This effect, which is pretty singular, probably arises from hence, that when the gold exceeds or even equals the silver in quantity, the parts of both being intimately united, the former are capable of coating over the latter, and covering them so as to defend them from the action of the *aqua fortis*; which is not the case when there is thrice as much silver as gold.

There is one thing more to be taken notice of with regard to this process; which is, that perfectly pure *aqua fortis* is rarely to be met with, for two reasons; first, it is difficult in making it wholly to prevent the rising of the medium employed to disengage the nitrous acid; that is, a little of the vitriolic acid will mix with the vapours of the *aqua fortis*: Secondly, unless the saltpetre be very well purified it will always hold some small portion of sea-salt, the acid of which, we know, is very readily set loose by the vitriolic acid, and consequently rises together with the vapours of the *aqua fortis*. It is easy to see that *aqua fortis* mixed either with the one or the other is not proper for the separating process; because, as has just been said, the vitriolic and the marine acid equally precipitate silver dissolved in the nitrous acid; by which means, when they are united with that acid they weaken its action upon the silver, and hinder the dissolution. Add that *aqua fortis* adulterated with a mixture of spirit of salt becomes an *aqua regis*, and consequently is rendered capable of dissolving gold,

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in proportion as its action upon silver is diminished.

In order to remedy this inconvenience, and free *aqua fortis* from the vitriolic or marine acid with which it is tainted, silver must be dissolved therein: by degrees, as the metal dissolves, those heterogeneous acids lay hold of it, and precipitate with it in the form of a white powder, as we observed before. This precipitate being wholly fallen, the liquor grows clear; after which, if it be found capable of dissolving more silver, without turning milky, it may be depended on as a perfectly pure *aqua fortis*. Then filtre it, dissolve more silver in it, as long as it will take up any, and you will have a solution of silver in a very pure *aqua fortis*. By means of this solution may other *aqua fortis* be purified: for pour a few drops thereof into a very impure *aqua fortis*, and immediately the vitriolic or marine acid, with which that *aqua fortis* is contaminated, will join the silver and fall therewith to the bottom. When the solution of silver prepared as above does not in the least affect the transparency of the *aqua fortis*, it is then very pure, and fit for the purposes of Quartation.

This operation of purifying *aqua fortis* by a solution of silver is called the *Precipitation* of *aqua fortis*; and *aqua fortis* thus purified is called *Precipitated aqua fortis*.

When silver is dissolved in *aqua fortis* it may be separated therefrom, as hath been shewn, by absorbent earths and fixed alkalis.

We shall see by and by that there are other means of effecting this; but whatever way it be separated from its solvent it recovers its metalline form, as gold does, by being simply fused without any addition.

§. III. *Of COPPER.*

Of all the imperfect metals copper comes the nearest to gold and silver. Its natural colour is a deep-red yellow. It resists a very violent degree of fire for a considerable time; but losing its Phlogiston at last, it changes its metalline form for that of a calx, or a pure reddish earth. This calx is hardly, if at all, reducible to glass, without the addition of something to promote its fusion; all that the fiercest heat can do being only to render it soft. Copper, even while it retains its metalline form, and is very pure, requires a considerable degree of fire to melt it, and does not begin to flow till long after it is red-hot. When in fusion, it communicates a greenish colour to the flame of the coals.

This metal is inferior to silver in point of gravity; nor is its ductility so great, tho' it be pretty considerable; but, on the other hand, it exceeds that metal in hardness. It unites readily with gold and silver; nor does it greatly lessen their beauty when added to them in a small quantity: nay, it even procures them some advantages; such as making them harder, and less subject to lose their ductility, of which those metals are often liable to be deprived, by the mixture of the smallest heterogeneous particle. This may probably arise from the circumstance, that the ductility of copper has the peculiarity of resisting most of those causes which rob the perfect metals of theirs.

The property, which other metalline substances have in common with copper, of losing the Phlogiston by calcining and then vitrifying, furnishes us with a method of separating them from gold and silver, when they are combined therewith. Nothing more is required than to expose the mass compounded of the perfect metals and other metalline substances

substances to a degree of heat sufficient to calcine whatever is not either gold or silver. It is evident that by this means these two metals will be obtained as pure as is possible: for, as hath already been said, no metalline calx or glass is capable of uniting with metals possessed of their phlogiston. On this principle is formed the whole business of refining gold and silver.

When the perfect metals have no other alloy but copper, as this metal is not to be calcined or vitrified without great difficulty, which is increased by its union with the unvitriifiable metals, it is easy to see that it is almost impossible to separate them without adding something to facilitate the vitrification of the copper. Such metals as have the property of turning easily to glass are very fit for this purpose; and it is necessary to add a certain quantity thereof, when gold or silver is to be purified from the alloy of copper. We shall have occasion to be more particular on this subject when we come to treat of lead.

Copper is soluble in all the acids, to which it communicates a green colour, and sometimes a blue. Even the neutral salts, and water itself, act upon this metal. With regard to water indeed, as the procuring it absolutely pure and free from any saline mixture is next to an impossibility, it remains a question whether the effect it produces on copper be not owing to certain saline particles contained in it. It is this great facility of being dissolved that renders copper so subject to rust; which is nothing else but some parts of its surface corroded by saline particles contained in the surrounding air and water.

The rust of copper is always green or blue, or of a colour between these two. Internally used it is very noxious, being a real poison, as are all the solutions of this metal made by any acid whatever. The blue colour, which copper constantly

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lumes when corroded by any saline substance, is sure sign by which it may be discovered wherever exists, even in a very small quantity.

Copper dissolved in the vitriolic acid forms a kind of metalline salt, which shoots into rhomboidal crystals of a most beautiful blue colour. These crystals are called *blue vitriol*, or *vitriol of copper*. They are sometimes found ready formed in the bowels of the earth; and may be artificially made by dissolving copper in the vitriolic acid; but the solution will not succeed unless the acid be well dephlegmated. The taste of this vitriol is saltish and stringent. It retains a considerable quantity of water in crystallizing, on which account it is easily rendered fluid by fire.

It must be observed that, when it is exposed to a certain degree of heat in order to free it of its humidity, a great part of its acid flies off at the same time: and hence it is that, after calcination, there remains only a kind of earth, or metalline calx, of red colour, which contains but very little acid. This earth cannot be brought to flow but with the greatest difficulty.

A solution of copper in the nitrous acid forms a salt which does not crystallize, but, when dried, powerfully attracts the moisture of the air. The same thing happens when it is dissolved in spirit of tartar, or in *aqua regis*.

If the copper thus dissolved by any of these acids be precipitated by an earth or an alkali, it retains nearly the colour it had in the solution: but these precipitates are scarce any thing more than the earthy copper, or copper deprived of most of its phlogiston; so that if they were exposed to a violent fire, without any additament, a great part of them would be converted into an earth that could never be reduced to a metalline form. Therefore, when we intend to reduce these precipitates to copper, it is necessary to add a certain quantity of a substance capable

capable of restoring to them the phlogiston they have lost.

The substance which hath been found fittest for such reductions is charcoal-dust; because charcoal is nothing but a phlogiston closely combined with an earth, which renders it exceedingly fixed, and capable of resisting a violent force of fire. But as charcoal will not melt, and consequently is capable of preventing rather than forwarding the flux of a metalline calx or glass, which nevertheless is essentially necessary to complete the reduction, it hath been contrived to mix it, or any other substance containing the phlogiston, with such fixed alkalis as easily flow, and are fit to promote the flux of other bodies. These mixtures are called *reducing fluxes*; because the general name of *fluxes* is given to all salts, or mixtures of salts, which facilitate fusion.

If sulphur be applied to copper made perfectly red-hot, the metal immediately runs; and these two substances uniting form a new compound much more fusible than pure copper.

This compound is destroyed by the sole force of fire, for two reasons: the first is, that sulphur being volatile, the fire is capable of subliming a great part of it, especially when it is in a great proportion to the copper with which it is joined; the second is, that the portion of sulphur which remains being more intimately united with the copper, though it be rendered less combustible by that union, is nevertheless burnt and consumed in time. Copper being combined with sulphur, and together with it exposed to the force of fire, is found to be partly changed into a blue vitriol; because the vitriolic acid, being disengaged by burning the sulphur, is by that means qualified to dissolve the copper. The affinity of copper with sulphur is greater than that of silver.

This metal, as well as the other imperfect metals

and the semi-metals, being mingled with nitre and exposed to the fire, is decomposed and calcined much sooner than by itself; because the phlogiston which it contains occasions the deflagration of the nitre; and consequently the two substances mutually decompose each other. There are certain metalline substances whose phlogiston is so abundant, and so weakly connected with their earth, that when they are thus treated with nitre, there arises immediately a detonation, accompanied with flame, and as violent as if sulphur or charcoal-dust had been employed; so that in a moment the metalline substance loses its phlogiston, and is calcined. The nitre, after these detonations, always assumes an alkaline character.

§. IV. OF IRON.

Iron is lighter and less ductile than copper; but it is much harder, and of more difficult fusion.

It is the only body that has the property of being attracted by the magnet, which therefore serves to discover it wherever it is. But it must be observed that it hath this property only when in its metalline state, and loses it when converted to an earth or calx. Hence very few iron-ores are attracted by the load-stone; because for the most part, they are only sorts of earths, which require a phlogiston to be added before they can be brought to the form of true iron.

When iron hath undergone no other preparation but the fusion which is necessary to smelt it from its ore, it is usually quite brittle, and flies to pieces under the hammer: which arises in some measure from its containing a certain portion of unmetallic earth interposed between its parts. This we call *pig iron*.

By melting this a second time it is rendered purer, and more free from heterogeneous matters:

but still, as its proper parts are probably not brought sufficiently near, or closely enough united, till the iron hath undergone some further preparation besides that of fusion, it seldom hath any degree of malleability.

The way to give it this property is to make it just red-hot, and then hammer it for some time in all directions; to the end that its parts may be properly united, incorporated, and welded together, and that the heterogeneous matters which keep them asunder may be separated. Iron made by this means as malleable as possible we call *bar iron*, or *forged iron*.

Bar iron is still harder to fuse than pig iron: to make it flow requires the utmost force of fire.

Iron has the property of imbibing a greater quantity of phlogiston than is necessary to give it the metalline form. It may be made to take in this superabundant phlogiston two ways: the first is by fusing it again with matters that contain the phlogiston; the second is, by encompassing it with a quantity of such matters, charcoal-dust for instance, and then exposing it so encompassed, for a certain time, to a degree of fire barely sufficient to keep it red-hot. This second method, whereby one substance is incorporated with another by means of fire, but without fusing either of them, is in general called *cementation*.

Iron thus impregnated with an additional quantity of phlogiston is called *steel*. The hardness of steel may be considerably augmented by *tempering* it; that is, by making it red-hot, and suddenly quenching it in some cold liquor. The hotter the metal, and the colder the liquor in which it is quenched, the harder will the steel be. By this means tools are made, such as files and sheers, capable of cutting and dividing the hardest bodies, as glass, pebbles, and iron itself. The colour of steel is darker than that of iron, and the facets which

which appear on breaking it are smaller. It is also less ductile and more brittle, especially when tempered.

As iron may be impregnated with an additional quantity of phlogiston, and thereby converted into steel, so may steel be again deprived of that superabundant phlogiston, and brought back to the condition of iron. This is effected by cementing it with poor earths, such as calcined bones and chalk. By the same operation steel may be *untempered*: nay, it will lose the hardness it had acquired by tempering, if it be but made red-hot, and left to cool gradually. As iron and steel differ only in the respects we have here taken notice of, their properties being in all other respects the same, what follows is equally applicable to both.

Iron being exposed to the action of fire for some time, especially when divided into small particles, such as filings, is calcined and loses its phlogiston. By this means it turns to a kind of reddish yellow earth, which on account of its colour is called *crocus martis*, or *saffron of Mars*.

This calx of iron has the singular property of glowing in the fire with somewhat less difficulty than iron itself; whereas every other metalline calx glows with less ease than the metal that produced it. It has moreover the remarkable property of uniting with the phlogiston, and of being reduced to iron without fusion; requiring for that purpose only to be made red-hot.

Iron may be incorporated with silver, and even with gold, by means of certain operations. Under the article of lead we shall see how it may be separated from these metals.

The acids produce on it much the same effects as on copper: every one of them acts upon it. Certain neutral salts, alkalis, and even water itself, are capable of dissolving it; and hence it is also very subject to rust. The vitriolic acid dissolves it

with the greatest ease: but the circumstances which attend the solution thereof are different from those with which the same acid dissolves copper: for, whereas the vitriolic acid must be concentrated to dissolve copper, it must on the contrary be diluted with water to dissolve iron, which it will not touch when well dephlegmated. 2. The vapours which rise in this dissolution are inflammable; so that if it be made in a small-necked bottle, and the flame of a candle be applied to the mouth thereof, the vapours in the bottle take fire with such rapidity as to produce a considerable explosion.

This solution is of a beautiful green colour; and from this union of the vitriolic acid with iron, there results a neutral metalline salt, which has the property of shooting into crystals of a rhomboidal figure, and a green colour. These crystals are called *green vitriol*, *vitriol of Mars*, and *copperas*.

Green vitriol hath a saltish and astringent taste. As it retains a great deal of water in crystallizing it quickly flows by the action of fire: but this fluidity is owing to its water only, and is not a real fusion; for as soon as its moisture is evaporated, it resumes a solid form. Its green transparent colour is now changed into an opaque white: and, if the calcination be continued, its acid also exhales and is dissipated in vapours; and as it loses that, it turns gradually to a yellow colour, which comes so much the nearer to a red the longer the calcination is continued, or the higher the force of the fire is raised; which being driven to the utmost, what remains is of a very deep red. This remainder is nothing but the body of the iron, which having lost its phlogiston is now no more than an earth, nearly of the same nature with that which is left after calcining the metal itself.

Green vitriol dissolved in water spontaneously lets fall a yellowish earthy sediment. If this solution be defecated by filtration, it still continues to deposit

deposite some of the same substance, till the vitriol is wholly decomposed. This sediment is nothing but the earth of iron, which is then called *Ochre*.

The nitrous acid dissolves iron with great ease. This solution is of a yellow colour, inclining more or less to a russet, or dark-brown, as it is more or less saturated with iron. Iron dissolved by this acid also, falls spontaneously in a kind of calx, which is incapable of being dissolved a second time; for the nitrous acid will not act upon iron that has lost its phlogiston. This solution does not crystallize, and evaporated to dryness attracts the moisture of the air.

Spirit of salt likewise dissolves iron, and this solution is green. The vapours which rise during the dissolution are inflammable, like those which ascend when this metal is attacked by the vitriolic acid. *Aqua regis* makes a solution of iron, which is of a yellow colour.

Iron hath a greater affinity than either silver or copper with the nitrous and vitriolic acids: so that if iron be presented to a solution of either in one of these two acids, the dissolved metal will be precipitated; because the acid quits it for the iron, with which it has a greater affinity.

On this occasion it must be observed that if a solution of copper in the vitriolic acid be precipitated by means of iron, the precipitate has the form and splendour of a metal, and does not require the addition of a phlogiston to reduce it to true copper; which is not the case, as has been shewn, when the precipitation is effected by earths or alkaline salts.

The colour of this metalline precipitate hath deceived several persons, who being unacquainted with such phenomena, and with the nature of blue vitriol, imagined that iron was transmuted into copper, when they saw a bit of iron laid in a solution of that vitriol, become, in form and external

ternal appearance, exactly like copper : whereas the surface only of the iron was crufted over with the particles of copper contained in the vitriol, which had gradually fallen upon and adhered to the iron, as they were precipitated out of the folution.

Among the folvents of iron we mentioned fixed alkalis ; and that they have fuch a power is proved by the following phenomenon. If a large proportion of alkaline falts be fuddenly mixed with a folution of iron in an acid, no precipitation enfues, and the liquor remains clear and pellucid ; or if at firft it look a little turbid, that appearance lafts but a moment, and the liquor prefently recovers its transparency. The reafon is, that the quantity of alkali is more than fufficient to faturate all the acid of the folution, and the fuperabundant portion thereof, meeting with the iron already finely divided by the acid, diffolves it with eafe as faft as it falls, and fo prevents its muddying the liquor. To evince that this is fo in fact, let the alkali be applied in a quantity that is not fufficient, or but barely fufficient, to faturate the acid, and the iron will then precipitate like any other metal.

Water alfo acts upon iron ; and therefore iron expofed to moifture grows rusty. If iron-filings be expofed to the dew, they turn wholly to a ruft, which is called *Crocus martis aperiens*.

Iron expofed to the fire together with nitre makes it detonate pretty briskly, fets in a flame, and decomposes it with rapidity.

This metal hath a greater affinity than any other metalline fubftance with fulphur ; on which account it is fuccefffully ufed to precipitate and feparate all metalline fubftances combined with fulphur.

Sulphur uniting with iron communicates to it fuch a degree of fufibility, that if a mafs of this metal heated red-hot be rubbed with a bit of fulphur, it inceffantly runs into as perfect a fufion as

metal exposed to the focus of a large burning-glass.

§. V. Of TIN.

Tin is the lightest of all metals. Though it yields easily to the impression of hard bodies, it has but little ductility. Being bent backwards and forwards makes a small crackling noise. It flows with a very moderate degree of fire, and long before it comes to be red-hot. When it is in fusion, its surface soon grows dusky, and there forms upon it a thin dark-coloured dusty pellicle, which is no other than a part of the tin that has lost its phlogiston, or a calx of tin. The metal thus calcined easily recovers its metalline form on the addition of a phlogiston. If the calx of tin be urged by a strong fire it grows white, but the greatest violence of heat will not fuse it; which makes some chymists consider it as a calcinable or absorbent earth, rather than a vitrifiable one. Yet it turns to glass, in some sort, when mixed with any other substance that vitrifies easily. However, it always produces imperfect glass only, which is not at all transparent, but of an opaque white. The calx of tin thus vitrified is called *enamel*. Enamels are made of several colours by the addition of this or that metalline calx.

Tin unites easily with all the metals; but it destroys the ductility and malleability of every one of them, lead excepted. Nay, it possesses this property of making metals brittle in such an eminent degree, that the very vapour of it, when in fusion, is capable of producing this effect. Moreover, which is very singular, the most ductile metals, even gold and silver, are those on which it works with the most ease, and in the greatest degree. It has also the property of making silver mixed with it flow over a very small fire.

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It adheres to, and in some measure incorporates with, the surface of copper and of iron; whence arose the practice of coating over those metals with tin. Tin-plates are no other than thin plates of iron tinned over.

If to twenty parts of tin one part of copper be added, this alloy renders it much more solid, and the mixed mass continues tolerably ductile.

If on the contrary to one part of tin ten parts of copper be added, together with a little Zink; a semi-metal to be considered hereafter, from this combination there results a metalline compound which is hard, brittle, and very sonorous; so that it is used for casting bells: this composition is called *Bronze and bell-metal*.

Tin hath an affinity with the vitriolic, nitrous and marine acids. All of them attack and corrode it; yet none of them is able to dissolve it without great difficulty: so that if a clear solution thereof be desired, particular methods must be employed for that purpose; for the acids do but in a manner calcine it, and convert it to a kind of white cal or precipitate. The solvent which has the greatest power over it is *aqua regis*, which has even a greater affinity therewith than with gold itself; whence it follows that gold dissolved in *aqua regis* may be precipitated by means of tin; but then the *aqua regis* must be weakened. Gold thus precipitated by tin is of a most beautiful colour, and is used for red in enamelling and painting on porcelain, as well as to give a red colour to artificial gems. If the *aqua regis* be not lowered, the precipitate will not have the purple colour.

Tin hath the property of giving a great lustre to all red colours in general; on which account it is used by the dyers for striking a beautiful scarlet, and tin vessels are employed in making fine syrups of violets. Water does not act upon this metal, it does upon iron and copper; for which reason

not subject to rust: nevertheless when it is exposed to the air its surface soon loses its polish and splendour.

Tin mixed with nitre and exposed to the fire degrades with it, makes it detonate, and is immediately converted to a *refractory calx*: for so all substances are called which are incapable of fusion.

Tin readily unites with sulphur, and with it becomes a brittle and friable mass.

§. VI. Of LEAD.

Next to gold and mercury lead is the heaviest of all metalline substances, but in hardness is exceeded by every one of them. Of all metals also it melts the easiest except tin. While it is in fusion there gathers incessantly on its surface, as on that of tin, a blackish dusty pellicle, which is nothing but a calx of lead.

This calx further calcined by a moderate fire, the flame being reverberated on it, soon grows white. If the calcination be continued it becomes yellow, and at last of a beautiful red. In this state it is called *Minium*, and is used as a pigment. *Minium* is not easily made, and the operation succeeds well in large manufactures only.

To convert lead into *litharge*, which is the metal in a manner half vitrified, you need only keep it melted by a pretty strong fire; for then as its surface gradually calcines, it tends more and more to fusion and vitrification.

All these preparations of lead are greatly disposed to perfect fusion and vitrification, and for that purpose require but a moderate degree of fire; the calx or earth of lead being of all metalline earths that which vitrifies the most easily.

Lead hath not only the property of turning into glass with the greatest facility, but it hath also that of promoting greatly the vitrification of all the other

ther imperfect metals; and, when it is actually vitrified, procures the ready fusion of all earths and stones in general, even those which are refractory, that is, which could not be fused without its help.

Glass of lead, besides its great fusibility, hath also the singular property of being so subtle and active as to corrode and penetrate the crucibles in which it is melted, unless they be of an earth that is exceeding hard, compact, and withal very refractory: for glass of lead being one of the most powerful fluxes that we know, if the earth of the crucible in which it is melted be in the smallest degree fusible, it will be immediately vitrified; especially if there be any metallic matter in its composition.

The great activity of glass of lead may be weakened by joining it with other vitrifiable matters: but unless these be added in a very great proportion, it will still remain powerful enough to penetrate common earths, and carry off the matters combined with it.

On these properties of lead, and of the glass of lead, depends the whole business of refining gold and silver. It hath been shewn that as these two metals are indestructible by fire, and the only ones which have that advantage, they may be separated from the imperfect metals, when mixed therewith, by exposing the compound to a degree of fire sufficiently strong to vitrify the latter; which when once converted into glass can no longer remain united with any metal that has its metalline form. But it is very difficult to procure this vitrification of the imperfect metals, when united with gold and silver; nay, it is in a manner impossible to vitrify them entirely, for two reasons: first, because most of them are naturally very difficult to vitrify; secondly, because the union they have contracted with the perfect metals defends them, in a manner, from the action of the fire, and that so much the more effectually

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fectually as the proportion of the perfect metals greater; which being indestructible, and in some coating over those with which they are alloyed, serve them as a preservative and impenetrable shield against the utmost violence of fire.

It is therefore clear that a great deal of labour may be saved, and that gold and silver may be refined to a much greater degree of purity than can otherwise be obtained, if to a mixture of these metals with copper, for instance, or any other imperfect metal be added a certain quantity of lead. For the lead, by its known property, will infallibly produce the desired vitrification; and as it likewise increases the proportion of the imperfect metals, and so lessens that of the perfect metals, in the mass, it evidently deprives the former of a part of their guard, and so effects a more complete vitrification. In conclusion, as the glass of lead hath the property of running through the crucible, and carrying with it the matters which it has vitrified, it follows that when the vitrification of the imperfect metals is effected by its means, all those vitrified matters together penetrate the vessel containing the fused metalline mass, disappear, and leave only the gold and silver perfectly pure, and freed, as far as is possible, from all admixture of heterogeneous parts.

The better to promote the separation of such parts it is usual to employ in this process a particular sort of small crucibles, made of the ashes of calcined bones, which are exceedingly porous and easily pervaded. They are called *cupels*, on account of their figure, which is that of a wide-mouthed cup: and from hence the operation takes its name; for when we refine gold and silver in this manner we are said to *cupel* those metals. It is easy to perceive that the more lead is added, the more accurately will the gold and silver be refined; and that the more lead ought to be added as the

perfect metals are alloyed with a greater proportion of the imperfect. This is the most severe trial to which a perfect metal can be put ; and consequently any metal that stands it may be fairly considered as such.

In order to denote the fineness of gold, it is supposed to be divided into twenty-four parts called *carats* ; and gold which is quite pure and free from all alloy is said to be twenty-four *carats fine* ; that which contains 1-24th part of alloy is called gold of twenty-three carats, that which contains 2-24ths of alloy is but twenty-two carats ; and so on. Silver again is supposed to be divided into twelve parts only, which are called *penny-weights* : so that when absolutely pure it is said to be twelve *penny-weights fine* ; when it contains 1-12th of alloy, it is then called eleven penny-weights fine ; when it contains 2-12th of alloy, it is called ten penny-weights fine, and so on.

In treating of copper we promised to shew, under the article of lead, how to separate it from iron. The process is founded on that property of lead which renders it incapable of mixing and uniting with iron, though it readily dissolves all other metalline substances. Therefore if you have a mass compounded of copper and iron, it must be fused with a certain quantity of lead, and then the copper, having a greater affinity with lead than with iron, will desert the latter and join the former, which being incapable of any union with iron, as was said, will wholly exclude it from the new compound. The next point is to separate the lead from the copper ; which is done by exposing the mass compounded of these two metals to a degree of fire strong enough to deprive the lead of its metalline form, but too weak to have the same effect on the copper : And this may be done ; since of all the imperfect metals lead is, next to tin, the easiest to be calcined, and copper on the contrary

ary resists the greatest force of fire longest, without losing its metalline form. Now what we gain by this exchange, viz. by separating copper from iron, and uniting it with lead, consists in this, that as lead is calcined with less fire than iron, the copper is less exposed to be destroyed: for it must be observed that, however moderate the fire be, it is hardly possible to prevent a certain quantity thereof from being calcined in the operation.

Lead melted with a third part of tin forms a compound, which being exposed to a fire capable of making it thoroughly red-hot, swells, puffs up, seems in some sort to take fire, and is presently calcined. These two metals mixed together are much sooner calcined than either of them separately.

Both lead and tin are in some measure affected by water, and by a moist air; but they are both much less subject than iron or copper to be corroded by these solvents, and of course are much less liable to rust.

The vitriolic acid acts upon and dissolves lead, much in the same manner as it doth silver.

The nitrous acid dissolves this metal with much ease, and in great quantities; and from this solution a small portion of mercury may be obtained. On this subject see our *Elements of the Practice of Chymistry*.

When this solution of lead is diluted with a good deal of water, the lead precipitates in the form of a white powder; which happens because the acid is rendered too weak to keep the lead dissolved.

If this solution of lead be evaporated to a certain degree, it shoots into crystals formed like regular pyramids with square bases. These crystals are of a yellowish colour, and of a saccharine taste: they do not easily dissolve in water. This nitrous metalline salt has the singular property of detonating

in a crucible, without any additament, or the contact of any other inflammable substance. This property it derives from the great quantity of phlogiston contained in, and but loosely connected with the lead which is one of its principles.

If spirit of salt, or even sea-salt in substance, be added to a solution of lead in the nitrous acid, a white precipitate immediately falls; which is no other than the lead united with the marine acid. This precipitate is extremely like the precipitate of silver made in the same manner, and that being called *Luna cornea* hath occasioned this to be named *plumbum corneum*. Like the *luna cornea* it is very fusible, and being melted hardens like it into a kind of horny substance: it is volatile, and may be reduced by means of inflammable matters combined with alkalis. But it differs from the *luna cornea* in this chiefly, that it dissolves easily in water; whereas the *luna cornea*, on the contrary, dissolves therein with great difficulty, and in a very small quantity.

As this precipitation of lead from its solution in spirit of nitre is procured by the marine acid, lead is thereby proved to have a greater affinity with the latter acid than with the former. Yet, if you attempt to dissolve lead directly by the acid of sea-salt, the solution is not so easily effected as by the spirit of nitre, and it is always imperfect; for it wants one of the conditions essential to every solution in a liquor. namely transparency.

If lead be boiled for a long time in a lixivium of fixed alkali, part of it will be dissolved.

Sulphur renders this metal refractory and scarce fusible; and the mass they form when united together is friable. Hence it appears that sulphur acts upon lead much in the same manner as upon tin; that is, it renders both these metals less fusible, which are naturally the most fusible of any, while it exceedingly facilitates the fusion of silver, copper,

er, and iron, metals which of themselves flow with the greatest difficulty.

C H A P. VIII.

Of QUICK-SILVER.

WE treat of quick-silver in a chapter apart, because this metallic substance cannot be classed with the metals properly so called, and yet has some properties which will not allow us to compound it with the semi-metals. The reason why quick-silver, by the chymists commonly called mercury, is not reputed a metal, is, that it wants one of the essential properties thereof, to wit, malleability. When it is pure and unadulterated with any mixture, it is always fluid, and of course unmalleable. But as, on the other hand, it eminently possesses the opacity, the splendour, and above all the gravity of a metal, being next to gold the heaviest of all bodies, it may be considered as a true metal, differing from the rest no otherwise than by being constantly in fusion; which we may suppose arises from its aptness to flow with such a small degree of heat, that be there ever so little warmth on earth, there is still more than enough to keep mercury in fusion; which would become solid and malleable if it were possible to apply to it a degree of cold considerable enough for that purpose. These properties will not allow us to compound it with the semi-metals. Add that we are not yet assured by any undoubted experiment that it can be wholly deprived of its phlogiston, as the imperfect metals may. Indeed we cannot apply the

force of fire to it as could be wished ; for it is so volatile that it flies off and exhales in vapours, with a much less degree of fire than is necessary to make it red-hot. The vapours of mercury thus raised by the action of fire, being collected and united in a certain quantity, appear to be no other than true mercury, retaining every one of its properties ; and no experiment hath ever been able to shew the least change thus produced in its nature.

If mercury be exposed to the greatest heat that it can bear without sublimation, and continued in it for several months, or even a whole year together, it turns to a red powder, which the chymists call *Mercurius præcipitatus per se*. But to succeed in this operation it is absolutely necessary that the heat be such as is above specified ; for this metallic substance may remain exposed to a weaker heat for a considerable number of years, without undergoing any sensible alteration.

Some chymists fancied that by this operation they had fixed mercury and changed its nature ; but without any reason : for if the mercury thus seemingly transmuted be exposed to a somewhat stronger degree of fire, it sublimes and exhales in vapours as usual ; and those vapours collected are nothing else but running mercury, which has recovered all its properties without the help of any additament.

Mercury has the property of dissolving all the metals, iron only excepted. But it is a condition absolutely necessary to the success of such dissolution, that the metalline substances be possessed of their phlogiston ; for if they be calcined, mercury cannot touch them : And hence it follows, that mercury doth not unite with substances that are purely earthy. Such a combination of a metal with mercury is called an *amalgam*. Trituration alone

alone is sufficient to effect it ; however, a proper degree of heat is also of use.

Mercury amalgamated with a metal gives it a consistence more or less soft, and even fluid, according to the greater or smaller proportion of mercury employed. All amalgams are softened by heat, and hardened by cold.

Mercury is very volatile ; vastly more so than the most unfixed metals : moreover the union it contracts with any metal is not sufficiently intimate to entitle the new compound resulting from that union to all the properties of the two substances united ; at least with regard to their degree of fixity and volatility. From all which it follows, that the best and surest method of separating it from metals dissolved by it, is to expose the amalgam to a degree of heat sufficient to make all the quick-silver rise and evaporate ; after which the metal remains in the form of a powder, and being fused recovers its malleability. If it be thought proper to save the quick-silver, the operation must be performed in close vessels, which will confine and collect the mercurial vapours. This operation is most frequently employed to separate gold and silver from the several sorts of earths and sands with which they are mixed in the ore ; because these two metals, gold especially, are of sufficient value to compensate the loss of mercury, which is inevitable in this process : besides, as they very readily amalgamate with it, this way of separating them from every thing unmetallic is very facile and commodious.

Mercury is dissolved by acids ; but with circumstances peculiar to each particular sort of acid.

The vitriolic acid, concentrated and made boiling hot, seizes on it, and presently reduces it to a kind of white powder, which turns yellow by the affusion of water, but does not dissolve in it : it is called *turbith mineral*. However, the vitriolic acid on this occasion unites with a great part of the mercury,

cury, in such a manner that the compound is soluble in water. For if to the water which was used to wash the turbith a fixed alkali be added, there falls instantly a ruffet-coloured precipitate, which is no other than mercury separated from the vitriolic acid by the intervention of the alkali.

This dissolution of mercury by the vitriolic acid is accompanied with a very remarkable phenomenon; which is, that the acid contracts a strong smell of volatile spirit of sulphur: a notable proof that part of the phlogiston of the mercury hath united therewith. And yet, if the mercury be separated by means of a fixed alkali, it does not appear to have suffered any alteration. Turbith mineral is not so volatile as pure mercury.

The nitrous acid dissolves mercury with ease. The solution is limpid and transparent, and as it grows cold shoots into crystals, which are a nitrous mercurial salt.

If this solution be evaporated to dryness, the mercury remains impregnated with a little of the acid, under the form of a red powder, which hath obtained the names of *red precipitate*, and *arcanum corallinum*. This precipitate, as well as turbith, is less volatile than pure mercury.

If this solution of mercury be mixed with a solution of copper, made likewise in the nitrous acid, and the mixture evaporated to dryness, there will remain a green powder called *green precipitate*. These precipitates are caustic and corrosive; and are used as such in surgery.

Though mercury be dissolved more easily and completely by the nitrous acid than by the vitriolic, yet it has a greater affinity with the latter than with the former: for if a vitriolic acid be poured into a solution of mercury in spirit of nitre, the mercury will quit the latter acid in which it was dissolved, and join the other which was added. The same thing

the Alkali. V. & Aromatic Oils are also said to precipitate the ϕ from ϕ nitrous acid. & when separated by means of the Volatile Alkali

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ning happens when the marine acid is employed in-
stead of the vitriolic.

Mercury combined with spirit of salt forms a sin-
gular body; a metalline salt which shoots into long
crystals, pointed like daggers. This salt is volatile,
and sublimes easily without decomposition. It is
moreover the most violent of all the corrosives hi-
therto discovered by chymistry. It is called *Corro-
sive Sublimate*, because it must absolutely be sublimed
to make the combination perfect. There are se-
veral ways of doing this: but the operation will
never fail, If the mercury be rarified into vapours,
and meet with the marine acid in a similar state.

Corrosive sublimate is dissolved by water, but in
very small quantities only. It is decomposed by
fixed alkalis, which precipitate the mercury in a
reddish yellow powder, called on account of its
colour *yellow precipitate*.

If corrosive sublimate be mixed with tin, and the
compound distilled, a liquor comes over which con-
tinually emits abundance of dense fumes, and from
the name of its inventor is called the *smoking liquor*
of *Libavius*. This liquor is no other than the tin
combined with the marine acid of the corrosive
sublimate, which therefore it hath actually decom-
pounded: whence it follows that this acid hath a
greater affinity with tin than with mercury.

The marine acid in corrosive sublimate is not
quite saturated with mercury, but is capable of
taking up a much greater quantity thereof. For if
corrosive sublimate be mixed with fresh mercury,
and sublimed a second time, another compound
will be produced containing much more mercury,
and less acrimonious; for which reason it is named
sweet sublimate of mercury, mercurius dulcis, aquila
alba. This compound may be taken internally,
and is purgative or emetic according to the dose
administered. It may be rendered still more gentle
by repeated sublimations, and then it takes the title
will not in its metallic state join with of
muratic acid. it must be reduced to a calx
before the acid will act on it.

Calomelas. of *panacea mercurialis*. No way hath hitherto been found to dissolve mercury in *aqua regis* without great difficulty, and even then it is but imperfectly dissolved.

Mercury unites easily and intimately with sulphur. If these two substances be only rubbed together in a gentle heat, or even without any heat, they will contract an union, though but an incomplete one. This combination takes the form of a black powder, which has procured it the name of *Æthiop's mineral*.

If a more intimate and perfect union be desired, this compound must be exposed to a stronger heat; and then a red ponderous substance will be sublimed, appearing like a mass of shining needles: this is the combination desired, and is called *cinabar*. In this form chiefly is mercury found in the bowels of the earth. Cinabar finely levigated acquires a much brighter red colour, and is known to painters by the name of *vermillion*.

Cinabar rises wholly by sublimation, without suffering any decomposition; because the two substances of which it consists, *viz.* mercury and sulphur, are both volatile.

Though mercury unites and combines very well with sulphur, as hath been said, yet it hath less affinity with that mineral than any other metal, Gold only excepted: whence it follows that any of the other metals will decompose cinnabar, by uniting with its sulphur, and so setting the mercury at liberty to appear in its usual form. Mercury thus separated from sulphur is esteemed the purest, and bears the name of *mercury revived from cinabar*.

Iron is generally used in this operation, preferably to the other metals, because among them all it has the greatest affinity with sulphur, and is the only one that has none with mercury.

Cinabar may also be decomposed by means of
fixed

ked alkalis; the affinity of these salts with sulphur being generally greater than that of any metalline substance whatever.



C H A P. IX.

Of the SEMI-METALS.

Of Regulus of Antimony. 2. Of Bismuth
3. Of Zinc. 4. Of Regulus of Arsenic.

§. I. *Of REGULUS OF ANTIMONY.*

Regulus of Antimony is a metallic substance, of a pretty bright white colour. It has the splendor, opacity, and gravity of a metal: but it is quite malleable, and crumbles to dust, instead of yielding or stretching under the hammer; on which account it is classed with the semi-metals.

It begins to flow as soon as it is moderately red; but, like the other semi-metals, it cannot stand a violent degree of fire; being thereby dissipated into smoke and white vapours, which adhere to such cold bodies as they meet with, and so are collected into a kind of *farina* called *flowers of antimony*.

If Regulus of antimony, instead of being exposed to a strong fire, be only heated so moderately that it shall not even melt, it will calcine, lose its logiston, and take the form of a greyish powder destitute of all splendor: this powder is called *calx of antimony*.

This calx is not volatile like the regulus, but will endure a very violent fire; and being exposed hereto will flow, and turn to a glass of the yellow-colour of a hyacinth.

It

It is to be observed, that the more the regulus is deprived of its phlogiston by continued calcination, the more refractory is the calx obtained from it. The glass thereof has also so much the less colour, and comes the nearer to common glass.

The calx and the glass of antimony will recover their metalline form, like every other calx and glass of a metal, if reduced by restoring to them their lost phlogiston. Yet if the calcination be carried too far, their reduction will become much more difficult, and a much smaller quantity of regulus will be resuscitated.

Regulus of antimony is capable of dissolving the metals; but its affinities with them are various, and differ according to the following order. It affects iron the most powerfully, next copper, then tin, lead, and silver. It promotes the fusion of metals, but makes them all brittle and unmalleable.

It will not amalgamate with mercury; and tho' by certain processes, particularly the addition of water and continued trituration, a sort of union between these two substances may be produced, yet it is but apparent and momentary; for being left to themselves and undisturbed they quickly disunite and separate*.

The vitriolic acid, assisted by heat, and even by distillation, dissolves regulus of antimony. The nitrous acid likewise attacks it; but the solution can by no art be made clear and limpid: so that the regulus is only calcined, in a manner, by this acid.

* N. Malouin, however, hath found a way to unite these two metallic substances: but then he does it by the interposition of sulphur; that is, he combines crude antimony with mercury. This combination is brought about in the same way that *Æthiops mineralis* is made; viz. either by fusion, or by trituration only without fire. It resembles the common *Æthiops*, and M. Malouin calls it *Æthiops of antimony*. He observed that mercury unites with antimony more intimately, by melting, than by rubbing them together.

The marine acid dissolves it well enough; but when it must be exceedingly concentrated, and applied in a peculiar manner, and especially by distillation. One of the best methods of procuring a perfect union between the acid of sea-salt and regulus of antimony, is to pulverize the latter, mix with corrosive sublimate, and distil the whole. There rises in the operation a white matter, thick, and scarce fluid, which is no other than the regulus of antimony united and combined with the acid of sea-salt. This compound is extremely corrosive, and is called *butter of antimony*.

It is plain that the corrosive sublimate is here decomposed; that the mercury is revived, and that the acid which was combined therewith hath quitted it to join the regulus of antimony, with which its affinity is greater. This butter of antimony by repeated distillations acquires a considerable degree of fluidity and limpidness.

If the acid of nitre be mixed with butter of antimony, and the whole distilled, there rises an acid liquor, or a sort of *aqua regis*, which still retains some of the dissolved regulus, and is called *bezoaric spirit of nitre*. After the distillation there remains a white matter, from which fresh spirit of nitre is again abstracted, and which being then washed with water is called *bezoar mineral*. This bezoar mineral is neither so volatile, nor so caustic, as butter of antimony; because the nitrous acid hath not the property of volatilizing metallic substances, as the marine acid does, and because it remains much more intimately combined with the reguline part.

If butter of antimony be mixed with water, the liquor immediately becomes turbid and milky, and a precipitate falls, which is nothing but the metallic matter partly separated from its acid, which is too much weakened by the addition of water to keep it dissolved. Yet this precipitate still retains a good deal

deal of acid; for which reason it continues to be a violent emetic, and in some degree corrosive. It hath therefore been very improperly called *mercurius vitæ*.

The proper solvent of regulus of antimony is *aqua regis*; by means whereof a clear and limpid solution of this semi-metal may be obtained.

Regulus of antimony mixed with nitre, and projected into a red-hot crucible, sets the nitre in a flame, and makes it detonate. As it produces this effect by means of its phlogiston, it must needs at the same time be calcined, and lose its metallic properties, which accordingly happens, and when the nitre is in a triple proportion to the regulus, the latter is so perfectly calcined as to leave only a white powder, which is fused with great difficulty, and then turns to a faintly coloured glass, not very different from common glass, and which is not reducible to a regulus by the addition of inflammable matter; at least it yields but a very small quantity thereof. If less nitre be used, the calx is not so white; the glass it produces is more like a metalline glass, and is more easily reduced. The calx of the regulus thus prepared by nitre is called, on account of the medicinal virtue ascribed to it, *diaphoretic antimony*, or *diaphoretic mineral*.

Nitre always becomes an alkali by deflagration, and in the present case retains part of the calx, which it even renders soluble in water. This calx may be separated from the alkali, if an acid be employed to precipitate it; and then it is called *materia perlata*. This pearly matter is a calx of antimony, so completely deprived of its phlogiston as to be altogether incapable of reduction to a regulus.

Regulus of antimony readily joins and unites with sulphur, forming therewith a compound which has a very faint metallic splendor. This compound appears like a mass of long needles adhering

ing together laterally; and under this form it is usually found in the ore, or at least when only separated by fusion from the stones and earthy matters with which the ore is mixed. It is called *crude antimony*.

Antimony flows with a moderate heat, and becomes even more fluid than other metallic substances. The action of fire dissipates or consumes the sulphur it contains, and its phlogiston also, so as to convert it into a calx and a glass, as it does the regulus.

Aqua regis, which we observed to be the proper solvent of the regulus, being poured on antimony, attacks and dissolves the reguline part, but touches not the sulphur; in consequence whereof it decomposes the antimony, and separates its sulphur from its regulus.

There are several other ways of effecting this decomposition, and obtaining the reguline part of antimony by itself: they consist either in destroying the sulphureous part of the antimony by combustion, or in melting the antimony with some substance, which has a greater affinity than its reguline part with sulphur. Most metals are very fit for this latter purpose: for though the regulus has a considerable affinity with sulphur, yet all the metals, except gold and mercury, have a greater.

If therefore iron, copper, lead, silver, or tin, be melted with antimony, the metal employed will unite with the sulphur, and separate it from the regulus.

It must be observed that, as these metals have some affinity with the regulus of antimony, the regulus will be joined in the operation by some of the metal employed as a *precipitant*, (so those substances are called which serve as the means of separating two bodies from each other); and therefore the regulus procured in this manner will not be absolutely pure: on this account care is taken to

distinguish each by adding the name of the metal employed in its precipitation; and thence come these titles, *martial regulus of antimony*, or only *martial regulus*, *regulus veneris*; and so of the rest.

Antimony is employed with advantage to separate gold from all the other metals with which it may be alloyed. It has been shewn that all the metals have a greater affinity, than the reguline part of antimony, with sulphur, gold only excepted; which is incapable of contracting any union therewith; and therefore, if a mass compounded of gold and several other metals be melted with antimony, every thing in that mass which is not gold will unite with the sulphur of the antimony. This union occasions two separations, to wit, that of the sulphur of the antimony from its reguline part, and that of the gold from the metals with which it was adulterated; and from the whole two new compounds arise; namely, a combination of the metals with the sulphur, which being lightest rises to the surface in fusion; and a metalline mass formed of the gold and the reguline part of the antimony united together, which being much the heaviest sinks to the bottom. There is no difficulty in parting the gold from the regulus of antimony with which it is alloyed: for the metalline mass need only be exposed to a degree of fire capable of dissipating into vapours all the semi-metal it contains; which being very volatile, the operation is much easier, and more expeditiously finished, than if the metals with which the gold was debased were to be vitrified on the cupel; without taking into the account that if silver were one of them, recourse must needs be had to the process of quartation after that of the cupel.

If equal parts of nitre and antimony be mixed together, and the mixture exposed to the action of fire, a violent detonation ensues; the nitre deflagrating

rating consumes the sulphur of the antimony, and even a part of its phlogiston. After the detonation there remains a greyish matter which contains fixed nitre, vitriolated tartar, and the reguline part of the antimony deprived in some measure of its phlogiston, and half vitrified by the action of the fire, which is considerably increased by the deflagration. This matter is called *liver of antimony*.

If instead of equal parts of nitre and antimony two parts of the former be used to one of the latter, then the reguline part loses much more of its phlogiston, and remains in the form of a yellowish powder.

Again, if three parts of nitre be taken to one of antimony, the regulus is thereby entirely robbed of its phlogiston, and converted to a white calx which bears the name of *Diaphoretic antimony*, or *Diaphoretic mineral*. The pearly matter may be precipitated by pouring an acid on the saline substances which here remain after the detonation, in the same manner as we shewed above was to be done with regard to the regulus.

In the two last operations, where the nitre is in double or triple proportion to the antimony, the reguline part is found after the detonation to be converted into a calx, and not into a half vitrified matter, which we have seen is the effect when equal parts only of nitre and antimony are used. The reason of this difference is, that in these two cases the reguline part, being wholly, or almost wholly, deprived of its phlogiston, becomes, as was observed, more difficult to fuse, and consequently cannot begin to vitrify in the same degree of heat as that which hath not lost so much of its phlogiston. If instead of performing the operation with equal parts of nitre and antimony alone, a portion of some substance which abounds with phlogiston be added, in that case the sulphur only of the antimony will be consumed, and the regulus

will remain united with its phlogiston and separated from its sulphur.

The regulus prepared in this manner is absolutely pure, because no metalline substance being employed, none can mix with and adulterate it. It is called *regulus of antimony per se*, or only *regulus of antimony*.

It is true indeed that in this operation much of the reguline part unavoidably loses its phlogiston and is calcined, and consequently a much smaller quantity of regulus is obtained than when metalline precipitants are employed: but this loss is easily repaired, if it be thought proper, by restoring to the calcined part its lost phlogiston.

Antimony melted with two parts of fixed alkali yields no regulus, but is entirely dissolved by the salt, and forms with it a mass of a reddish yellow colour.

The reason why no precipitate is produced on this occasion is, that the alkali uniting with the sulphur of the antimony forms therewith the combination called *liver of sulphur*, which by its nature is qualified to keep the reguline part dissolved. This mass formed by the union of the antimony with the alkali is soluble in water. If any acid whatever be dropt into this solution, there falls a precipitate of a reddish yellow colour; because the acid unites with the alkali, and forces it to quit the matters with which it was combined. This precipitate is called *golden sulphur of antimony*.

As in the operation for preparing *regulus of antimony per se*, some of the nitre is, by the inflammable matters added thereto, turned to an alkali, this alkali seizes on part of the antimony, and therewith forms a compound like that just described. Hence it comes that if the scoria formed in this process be dissolved in water, and an acid dropped into the solution, a true golden sulphur of antimony is thereby separated.

This

This union of antimony with an alkali may also be brought about by the humid way; that is, by making use of an alkali resolved into a liquor, and boiling the mineral in it. The alkaline liquor, in proportion as it acts upon the antimony, gradually becomes reddish and turbid. If left to settle and cool when well saturated therewith, it gradually deposits the antimony it had taken up, which precipitates in the form of a red powder: and this precipitate is the celebrated remedy known by the name of *Kermes mineral*. It is plain that the kermes is nearly the same thing with the golden sulphur: yet it differs from it in some respects; and especially in this, that being taken inwardly it operates much more gently than the golden sulphur, which is a violent emetic. Nitre fixed by charcoal, and resolved into a liquor, is the only alkali employed in preparing the kermes.

It was shewn above, that regulus of antimony mixed and distilled with corrosive sublimate decomposes it, disengages the mercury, and joining itself to the marine acid forms therewith a new combination, called butter of antimony. If the same operation be performed with crude antimony instead of its regulus, the same effects are produced: but then the antimony itself is also decomposed; that is, the reguline part is separated from the sulphur, which being set free unites with the mercury, now also at liberty, and these two together form a true cinabar, called *cinabar of antimony*.

§. II. Of BISMUTH.

Bismuth, known also by the name of tin-glass, is a semi-metal, having almost the same appearance as regulus of antimony; yet it has a more dusky cast, inclining somewhat to red, and even presents some

some changeable streaks, especially after lying long in the air.

When exposed to the fire it melts long before it is red, and consequently with less heat than regulus of antimony, which does not flow, as was shewn above, till it begin to be red-hot. It becomes volatile, like all the other semi-metals, when acted on by a violent fire; being kept in fusion by a proper degree of heat it loses its phlogiston with its metallic form, and turns to a powder or a calx; and that again is converted into glass by the continued action of fire. The calx and glass of bismuth may be reduced, like any other metallic calx, by restoring their phlogiston.

Bismuth mixes with all the metals in fusion, and even facilitates the fusion of such as do not otherwise flow readily. It whitens them by its union, and destroys their malleability.

It amalgamates with mercury, if they be rubbed together with the addition of water: yet, after some time, these two metalline substances desert each other, and the bismuth appears again in the form of a powder. Hence it is plain, that the union it contracts with mercury is not perfect; and yet it has the singular property of attenuating lead, and altering it in such a manner that it afterwards amalgamates with mercury much more perfectly, so as even to pass with it through shamoy leather without any separation. The bismuth employed in making this amalgama afterwards separates from it spontaneously, as usual; but the lead still continues united with the mercury, and always retains the property thus acquired.

The vitriolic acid does not dissolve bismuth: its proper solvent is the nitrous acid, which dissolves it with violence, and abundance of fumes.

Bismuth dissolved in the nitrous acid is precipitated not only by alkalis, but even by the bare addition of water. This precipitate is extremely
white

white, and known by the name of *Magistery of Bismuth*.

The acid of sea-salt and *aqua regis* likewise act upon bismuth, but with less violence.

This semi-metal does not sensibly deflagrate with nitre; yet it is quickly deprived of its phlogiston, and turned into a vitrifiable calx, when exposed with it to the action of fire.

It readily unites with sulphur in fusion; and forms therewith a compound which appears to consist of needles adhering laterally to each other.

It may be separated from the sulphur with which it is combined, by only exposing it to the fire, without any additament; for the sulphur is either consumed or sublimed, and leaves the bismuth behind.

§. III. Of ZINC.

Zinc to appearance differs but little from bismuth, and has even been confounded with it by several authors. Nevertheless, besides that it has something of a blueish cast, and is harder than bismuth, it differs from it essentially in its properties, as will presently be shewn. These two metallic substances scarce resemble each other in any thing, but the qualities common to all semi-metals.

Zinc melts the moment it grows red in the fire, and then also begins to turn to a calx, which, like any other metallic calx, may be reduced by means of the phlogiston: but, if the fire be considerably increased, it sublimes, flames, and burns like an oily matter; which is a proof of the great quantity of phlogiston in its composition. At the same time abundance of flowers rise from it in the form of white flakes, flying about in the air like very light bodies; and into this form may the whole substance of the zinc be converted. Several names have been given to these flowers, such as pompholyx, philosophic

The flowers of Zinc may be easily reduced. philosophic wool. They are supposed to be no other than the zinc itself deprived of its phlogiston; yet no body has hitherto been able to resuscitate them in the form of zinc, by restoring their phlogiston according to the methods used in the reduction of metals. Though they rise in the air with very great ease while the zinc is calcining, yet when once formed they are very fixed; for they withstand the utmost violence of fire, and are capable of being vitrified, especially if joined with a fixed alkali. They are soluble in acids.

Zinc unites with all metalline substances, except bismuth. It has this singular property, that being mixed with copper, even in a considerable quantity, such as a fourth part, it does not greatly lessen the ductility thereof, and at the same communicates to it a very beautiful colour not unlike that of gold; on which account the composition is frequently made, and produces what is called *brass*. This metal melts much more easily than copper alone, because of the zinc with which it is alloyed. If it be exposed to a great degree of heat, the zinc which is contained takes fire, and sublimed in white flowers, just as when it is pure.

It is to be observed that brass is ductile only while it is cold, and not then unless the zinc used in making it was very pure; otherwise the composition will prove but a *tombac* or *prince's metal*, having very little malleability.

Zinc is very volatile, and carries off with it any metallic substance with which it is fused, making a kind of sublimate thereof. In the furnaces where they smelt ores containing zinc, the matter thus sublimed is called *cadmia fornacum*, to distinguish it from the native *cadmia* called also *calamine*, or *lapis calimmaris*: which properly speaking, is an ore of zinc, containing a great deal of that semi-metal, together with some iron, and a stony substance. The name of *cadmia fornacum* is not appropriated solely

lately to the metallic sublimes procured by means of zinc, but is given in general to all the metallic sublimes found in smelting houses.

If a violent and sudden heat be applied to zinc, it sublimes in its metalline form; there not being time for it to burn and be resolved into flowers.

This semi-metal is soluble in all the acids, but especially in spirit of nitre, which attacks and dissolves it with very great violence.

Zinc has a greater affinity than iron or copper with the vitriolic acid; and therefore it decomposes the green and blue vitriols, precipitating those two metals by uniting with the vitriolic acid, with which it forms a metallic salt, or vitriol, called *white vitriol*, or *vitriol of zinc*.

Nitre mixed with zinc, and projected into a red-hot crucible, detonates with violence, and during the detonation, there rises a great quantity of white flowers, like those which appear when it is calcined by itself.

Sulphur has no power over zinc. Even liver of sulphur, which dissolves all other metallic substances, contracts no union with this semi-metal.

Messrs. Hellot and Molouin have bestowed a great deal of pains on this semi-metal. An account of their experiments is to be found in the Memoirs of the Academy of Sciences.

§. IV. Of REGULUS OF ARSENIC.

Regulus of Arsenic is the most volatile of all the semi-metals. A very moderate heat makes it wholly evaporate, and fly off in fumes: on which account it cannot be brought to fusion, nor can any considerable masses thereof be obtained. It has a metallic colour, somewhat resembling lead; but soon loses its splendour when exposed to the air. It unites readily enough with metallic substances, having the same affinities with them as regulus of antimony

antimony hath. It makes them brittle, and unmalleable. It hath also the property of rendering them volatile, and greatly facilitates their scorification.

It very easily parts with its phlogiston and its metallic form. When exposed to the fire it rises in a kind of shining crystalline calx, which on that account looks more like a saline matter than a metallic calx. To this calx or these flowers are given the names of *white arsenic*, *crystalline arsenic*, and most commonly plain *arsenick*.

The properties of this substance are very singular, and extremely different from those of any other mettalic calx. Hitherto it hath been but little examined; and this led me to make some attempts towards discovering its nature, which may be seen in the memoirs of the academy of sciences.

Arsenic differs from other metalline calx, first, in being volatile; whereas the calxes of all other metallic substances, not excepting those of the most volatile semi-metals, such as regulus of antimony and zinc, are exceedingly fixed; and secondly, in having a saline character, which is not found in any other metalline calx.

The saline character of arsenic appears, first, from its being soluble in water: secondly, from its corrosive quality, which makes it one of the most violent poisons; a quality from which the other metallic substances are free, when they are not combined with some saline matter. Regulus of antimony must however be excepted. But then the best chymists agree, that this semi-metal is either nearly of the same nature with arsenic, or contains a portion thereof in its composition: besides, its noxious qualities never discover themselves so plainly as when it is combined with some acid. Lastly, Arsenic acts just like the vitriolic acid upon nitre; that is, it decomposes that neutral salt, by expelling its acid from its alkaline basis, of which

which it takes possession, and therewith forms a new saline compound.

This combination is a species of salt that is perfectly neutral. When the operation is performed in a close vessel, the salt shoots into crystals in the form of right-angled quadrangular prisms, terminated at each extremity by pyramids that are also quadrangular and right-angled; some of which however, instead of ending in a point, are obtuse as if truncated. The consequence is different when the operation is performed in an open vessel; for then nothing is obtained but an alkaline salt impregnated with arsenic, which cannot be crystallized.

The cause of this different effect is that, when the arsenic is once engaged in the alkaline basis of the nitre, it can never be separated from it by the utmost force of fire, so long as it is kept in a close vessel; whereas, if you expose it to the fire without that precaution, it readily separates from it. This property of arsenic was never before observed by any chymist, and therefore this our new species of neutral arsenical salt was absolutely unknown till lately.

This new salt possesses many singular properties, the chief of which are these. First, it cannot be decomposed by the intervention of any acid, even the strongest acid of vitriol; and this, joined to its property of expelling the nitrous acid from its basis, shews that it has a very great affinity with fixed alkalis.

Secondly, this very salt, on which pure acids have no effect, is decomposed with the greatest ease by acids united with metallic substances. The reason of this phenomenon is curious, and furnishes us with an instance of what we advanced concerning double affinities.

If to a solution of any metallic substance whatever, made by any acid whatever, (except that of

Mercury by the marine acid, and that of gold by *aqua regis*), a certain quantity of our new salt dissolved in water be added, the metallic substance is instantaneously separated from the acid in which it was dissolved, and falls to the bottom of the liquor.

All metallic precipitates obtained in this manner are found to be a combination of the metal with arsenic; whence it necessarily follows that the new neutral salt is by this means decomposed, its arsenical part uniting with the metallic substance, and its alkaline basis with the acid in which that substance was dissolved.

The affinities of these several bodies must be considered as operating on this occasion in the following manner: The acids which tend to decompose the neutral salt of arsenic, by virtue of their affinity with its alkaline basis, are not able to accomplish it, because this affinity is powerfully counteracted by that which the arsenic has with the same alkaline basis, and which is equal or even superior to theirs. But if these acids happen to be united with a substance which naturally has a very great affinity with the arsenical part of the neutral salt, then, the two parts of which this salt consists, being drawn different ways by two several affinities tending to separate them from each other, the salt will undergo a decomposition, which could not have been effected without the help of this second affinity. Now as metallic substances have a great affinity with arsenic, it is not surprising that the neutral salt of arsenic, which cannot be decomposed by a pure acid, should nevertheless yield to an acid combined with a metal. The decomposition of this salt, therefore, and the precipitation which of course it produces in metallic solutions, are brought about by the means of a double affinity; namely, that of the acid with the alkaline basis of the neutral salt, and

and that of the metal with the arsenical part of that salt.

Arsenic has not the same effect on sea-salt as on nitre, and cannot expel its acid: a very singular phenomenon, for which it is hard to assign a reason; for the nitrous acid is known to have a greater affinity than the marine acid with alkalis, and even with the basis of sea-salt itself.

Yet arsenic may be combined with the basis of sea-salt, and a neutral salt thereby obtained, like that which results from the decomposition of nitre by arsenic: but for that purpose a quadrangular nitre must be first prepared, and arsenic applied thereto as to common nitre.

The salt produced by uniting arsenic with the basis of sea-salt very much resembles the neutral salt of arsenic above treated of, as well in the figure of its crystals as in its several properties.

Arsenic presents another singular phenomenon, both with the alkali of nitre and with that of sea-salt; which is, that if it be combined with these salts in a fluid state, it forms with them a saline compound, quite different from the neutral salts of arsenic which result from the decomposition of nitrous salts.

This saline compound, which I call *Liver of arsenic*, takes up a much greater quantity of arsenic than is necessary for the perfect saturation of the alkali. It has the appearance of a glue, which is so much the thicker the more arsenic it contains. Its smell is disagreeable; it attracts the moisture of the air, and does not crystallize; it is easily decomposed by any acid whatever, which precipitates the arsenic and unites with the alkali. Lastly, the effects it produces on metallic solutions are different from those of our neutral arsenical salts. But the bounds which I have set myself in this treatise will not allow me to be more particular. Such as have the curiosity to inquire further into the subject

may consult my dissertations on arsenic, published among the memoirs of the academy of sciences.

Arsenic is easily reduced to a regulus. It need only be mixed with any matter containing the phlogiston, and by the help of a moderate heat a true regulus will sublime. This regulus, as was said, is very volatile, and calcines with the greatest ease; which is the reason why it cannot be obtained but in small quantities, and also why, in order to obtain masses of it, some have thought of adding thereto some metal with which it has a great affinity, such as copper or iron; because by joining with the metal it is partly fixed and restrained from flying off. But it is plain the regulus obtained by this means is not pure, as it must partake considerably of the metal employed.

Arsenic readily unites with sulphur, and rises with it in a yellow compound called *Orpiment*.

Sulphur cannot be separated from arsenic but by the intervention of two bodies only; to wit, a fixed alkali and Mercury.

The property which Mercury possesses of separating sulphur from arsenic is founded on this, that these two metallic substances are incapable of contracting any union; whereas though most of the other metals and semi-metals have a greater affinity with sulphur than Mercury hath, as was shewn in treating of the decomposition of cinabar, nevertheless they are all unable to decompose orpiment; because some of them have as great an affinity with arsenic as with sulphur; others have no affinity with either; and lastly, sulphur hath as great an affinity with arsenic as with any of them.

It must be observed that, if fixed alkalis be employed to purify arsenic in this manner, no more must be used than is necessary to absorb the sulphur or the phlogiston, of which also it is their nature to deprive arsenic; for otherwise as it has been

shewn,

shewn, that arsenic readily unites with alkalis, they would absorb a considerable quantity thereof.



C H A P. X.

Of OIL in general.

1. Of charcoal. 2. Of soap.

OIL is an unctuous body, which burns and consumes with flame and smoke, and is not soluble in water. It consists of the phlogiston united with water by means of an acid. There is moreover in its composition a certain proportion of earth, more or less according to each several sort of oil.

The inflammability of oil evidently proves that it contains the phlogiston. That an acid is one of its constituent principles many experiments demonstrate, of which these are the chief: If certain oils be long triturated with an alkaline salt, and the alkali afterwards dissolved in water, crystals of a true neutral salt will be produced: some metals, and particularly copper, are corroded and rusted by oils, just as they are by acids: again, acid crystals are found in some oils that have been long kept. This acid in oil serves undoubtedly to unite its phlogiston with its water; because these two substances having no affinity with each other cannot be united without the intervention of such a medium as an acid, which has no affinity with both. As to the existence of water in oils, it appears plainly when they are decomposed by repeated distillations, especially after mixing them with absorbent earths. Lastly, when an oil is destroyed by burning,

burning, a certain quantity of earth is constantly left behind.

We are very sure that the above mentioned principles enter into the composition of oils; for they may be obtained from every one of them: but it is not absolutely certain that they consist of these only, and that they do not contain some other principle which may escape our notice in decomposing them; for hitherto it doth not appear, by any experiment we can depend on, that oil was ever produced by combining together the principles here specified: yet such redintegrations are the only means we have of satisfying ourselves that we know all the principles which constitute a body.

Oils exposed to the fire in close vessels pass over almost wholly from the containing vessel into any other applied to receive them. There remains, however, a small quantity of black matter, which is extremely fixed, and continues unalterable as long as it hath no communication with the external air, be the force of the fire ever so violent. This matter is no other than part of the phlogiston of the oil united with its most fixed and grossest earth; and this is what we called *charcoal*, or plainly a *coal*.

§. I. Of CHARCOAL.

When oil happens to be united to much earth, as it is in vegetable and animal bodies, it leaves a considerable quantity of *coal* or charred matter.

This coal, exposed to the fire in the open air, burns and wastes, but without blazing like other combustible matters: there appears only a small blueish flame, but not the least smoke. Most commonly it only glows and sparkles, and so gradually falls into ashes, which are nothing but the earth of the body, combined with an alkaline salt in burning. This alkaline salt may be separated from the earth,

earth, by lixiviating the ashes with water, which dissolves all the salt, and leaves the earth quite pure.

Charcoal is unalterable and indestructible by any other body but fire; whence it follows, that when it is not actually kindled and ignited, the most powerful agents, such as the acids, though ever so strong and concentrated, have not the least effect on it.

The case is otherwise when it is lighted; that is, when its phlogiston begins to separate from its earth; for then the pure acid of vitriol being joined therewith contracts an instantaneous union with its phlogiston, and evaporates in a volatile sulphureous spirit. If the vitriolic acid, instead of being applied quite pure, be first clogged with some basis, especially an alkaline one, it quits that basis, enters into a more intimate union with the phlogiston of the burning coal, and so forms an actual sulphur, with which the alkali now unites and forms a hepar.

The pure acid of sea-salt hath not been observed to act in the least upon charcoal, especially when it is not on fire. But when this acid is incorporated with an alkaline or metallic basis, and combined according to a peculiar process with burning charcoal, it in like manner quits its basis, unites with the phlogiston, and therewith forms a phosphorus, of which we have already taken notice.

Nor has the pure nitrous acid any effect on a charred coal, even when ignited: and so far is it from being able to kindle a cold one, that when poured on a live one, it extinguishes it like water. But when this acid is united with a basis, it quits it rapidly as soon as it touches a burning-coal, and rushes violently into an union with the phlogiston thereof. From this union there probably arises, as we said before, a kind of sulphur or phosphorus, which is so inflammable as to be destroyed by the fire the very moment it is generated.

The

The acids of nitre and vitriol act upon oils; but very differently, according to the quantity of phlegm they contain. If they be weakened with much water, they have no effect at all upon oils; if they contain little water, or be dephlegmated to a certain degree, they dissolve them with heat, and with them form compounds of a thick consistence. Acids thus combined in a considerable proportion with oils render them soluble in water.

§. II. Of Soap.

Alkalis also have the same property. When any oil is combined with an acid or an alkali in such a manner that the compound resulting from their union is soluble in water; such a compound may in general be called a *Soap*. Soap itself hath the property of rendering fat bodies in some measure soluble in water; on which account it is very useful for scouring or cleansing any thing greasy.

Oily and saline substances, combined together, observe the same general rules as all other combinations; that is, they mutually communicate the properties belonging to each: thus oils, which naturally are not soluble in water, acquire by their union with saline matters the property of dissolving therein; and salts lose by their conjunction with oils part of their natural tendency to incorporate with water; so that while they serve to constitute soap they do not, as before, attract the moisture of the air, &c. and in like manner, as they are not inflammable, they considerably lessen the inflammability of the oils combined with them.

Acid soaps are decomposed by alkalis, as alkaline soaps are by acids, according to the general rules of affinities.

The acids of nitre and vitriol, when highly concentrated, dissolve oils with such violence as to heat them, make them black, burn them, and even set them

them on fire. How sea-salt affects oils is not yet sufficiently ascertained.

All oils have the property of dissolving sulphur; which is not at all surprising, seeing each of its component principles hath an affinity with oil.

It is also a property common to all oils to become more fluid, subtle, light, and limpid the oftener they are distilled. On the contrary, by being incorporated with saline substances they acquire a greater consistence, and sometimes form compounds that are almost solid.



C H A P. XI.

Of the several sorts of OILS.

1. Of Mineral Oils. 2. Of Vegetable Oils. 3. Of Animal Oils.

OILS are distinguished by the substances from which they are drawn: and as oils are extracted from minerals, from vegetables, and from animals, there are of course mineral, vegetable, and animal oils.

§. I. *Of MINERAL OILS.*

In the bowels of the earth we find but one sort of oil, called *petroleum*: its smell is strong and not agreeable, and its colour sometimes more sometimes less yellow. There are certain mineral substances which yield by distillation a great deal of oil very like petroleum. This sort of substance is called a *bitumen*, and is indeed nothing but an oil rendered consistent and solid by being combined with an

an acid ; as appears from hence, that by uniting petroleum with the acid of vitriol we can produce an artificial bitumen very like the native.

§. II. Of VEGETABLE OILS.

Vegetable substances yield a very great quantity and variety of oils : for there is not a plant, or part of a plant, that does not contain one or more sorts thereof, generally peculiar to itself, and different from all others.

By expression only, that is, by bruizing and squeezing vegetable substances, particularly certain fruits and seeds, a sort of oil is obtained which has scarce any smell or taste. Oils of this sort are very mild and unctuous ; and, because in this respect they resemble animal fat more than the rest do, they are called *fat oils*.

These oils, being exposed to the air for some time, sooner or latter grow thick, acquire an acrid taste, and a strong disagreeable smell. Some of them congeal with the smallest degree of cold. This sort of oil is well adapted to dissolve those preparations of lead called litharge and minium, with which they form a thick tenacious substance, that is used for the basis of almost all plaisters. They also dissolve lead in its metalline form ; but not so easily as the sorts of calx abovementioned ; probably because its body is not so much opened, nor its parts so divided.

By expression alone we also procure from certain vegetable substances another sort of oil, which is thin, limpid, volatile, of a pungent taste, and retains the smell of the vegetable that yielded it ; on which account it is called an *essential oil*. Of this there are several sorts, differing from one another, like the fat oils, according to the subjects from which they are obtained.

We must observe that it is very difficult, or rather

ner in most cases impossible, to force from the greatest part of vegetables, by expression only, all the essential oil they contain. For this purpose therefore recourse must be had to fire: a gentle heat, not exceeding that of boiling water, will extract all the essential oils of vegetables; and this is the most usual and most convenient way of procuring them.

The fat oils cannot be obtained by the same method: these being much less volatile than the essential oils, require a much greater degree of heat to raise them; which nevertheless they cannot bear without being much spoiled and entirely changed in their nature, as shall presently be shewn. All oils, therefore, which rise with the heat of boiling water, and such alone, should be called essential oils.

Essential oils, in a longer or shorter time, according to the nature of each, lose the fragrant smell they had when newly distilled, and acquire another, which is strong, rancid, and much less agreeable: they also lose their tenuity, becoming thick and viscid; and in this state they greatly resemble those substances abounding in oil which flow from certain trees, and which are called *balsams* or *resins*, according as they are less or more consistent.

Balsams and resins are not soluble in water. But there are other oily compounds which likewise run from trees; and, though not unlike resins, are however soluble in water. These are called *gums*; and their property of dissolving in water arises from their containing more water and more salt than resins have; or at least their saline parts are less clogged and more disengaged.

Balsams and resins distilled with the heat of boiling water, yield great quantities of a limpid, subtle, odoriferous, and, in one word, essential oil. In the still there remains a substance thicker and more consistent

consistent than the balsam or resin was before distillation. The same thing happens to essential oils which by length of time have acquired a consistence and are grown resinous. If they be redistilled, they recover their former tenuity, leaving behind them a remainder thicker and more resinous than they themselves were. This second distillation is called the *rectification* of an oil.

It must be observed that an essential oil, combined with an acid strong enough to dissolve it, immediately becomes as thick and resinous, in consequence of this union, as if it had been long exposed to the air: which proves the consistence an oil acquires by long keeping to be owing to this, that its lightest and less acid parts being evaporated, the proportion of its acid to the remainder is so increased, that it produces therein the same change, as an additional acid mixed with the oil would have wrought before the evaporation.

This also shews us that balsams and resins are only essential oils combined with a great proportion of acid, and thereby thickened.

If vegetable substances, from which no more essential oil can be drawn, by the heat of boiling water, be exposed to a stronger heat, they yield an additional quantity of oil; but it is thicker and heavier than the essential oil. These oils are black, and have a very disagreeable burnt smell, which hath made them be called *fetid*, or *empyreumatic* oils. They are moreover very acrid.

It must be observed that, if a vegetable substance be exposed to a degree of heat greater than that of boiling water, before the fat or the essential oil is extracted from it, an empyreumatic oil only will then be obtained; because both the fat and essential oils, when exposed to the force of fire, are thereby burnt, rendered acrid, acquire a smell of the fire, and, in a word, become truly empyreumatic. There is ground to think, that an empyreumatic oil is nothing

hing else but an essential or fat oil burnt and spoiled by the fire, and that no other oil besides these two exists naturally in vegetables.

Empyreumatic oils, distilled and rectified several times by a gentle heat, acquire by every distillation a greater degree of tenuity, lightness, and limpidity. By this means also they lose something of their disagreeable odour; so that they gradually come nearer and nearer to the nature of essential oils: and if the rectifications be often enough repeated, ten or twelve times for instance, they become perfectly like those oils; except that their smell will never be so agreeable, nor like that of the substances from which they were obtained.

Fat oils may also be brought by the same means to resemble essential oils: but neither essential nor empyreumatic oils are capable of acquiring the properties of fat oils.

§. II. *Of ANIMAL OILS.*

Distillation procures us considerable quantities of oil from all the parts of animal bodies, and especially from their fat. This oil at first is not very fluid, and is extremely fetid: but by many rectifications it gradually acquires a great degree of clearness and tenuity, and at the same time loses much of its disagreeable odour. Animal oils, thus rendered thin and fluid by a great number of rectifications, have the reputation of being an excellent medicine, and a specific in the epilepsy.



C H A P. XII.

Of FÉRMÉNTATION in general.

BY fermentation is meant an intestine motion, which, arising spontaneously among the insensible parts of a body, produces a new disposition and a different combination of those parts.

To excite a fermentation in a mixt body it is necessary first, that there be in the composition of that mixt a certain proportion of watery, saline, oily, and earthy parts: but this proportion is not yet sufficiently ascertained. Secondly, it is requisite that the body to be fermented be placed in a certain degree of temperate heat: for much cold obstructs fermentation; and too much heat decomposes bodies. Lastly, the concurrence of the air is also necessary to fermentation.

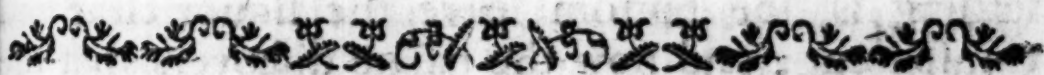
All vegetable and animal substances are susceptible of fermentation, because all of them contain in a due proportion the principles above specified. However, many of them want the proper quantity of water, and cannot ferment while they remain in such a state of dryness. But it is easy to supply that defect, and so render them very apt to ferment.

With respect to minerals properly so called, (that is, excluding such vegetable and animal substances as may have lain long buried in the earth,) they are not subject to any fermentation; at least that our senses can perceive.

There are three sorts of fermentation, distinguished from one another by their several productions. The first produces wines and spirituous liquors; for which

which reason it is called the *vinous* or *spirituous fermentation*: the result of the second is an acid liquor; and therefore it is called the *acetous fermentation*: and the third generates an alkaline salt; which, however, differs from the alkaline salts hitherto treated of, in this respect chiefly, that instead of being fixed, it is extremely volatile: this last sort takes the name of the *putrid* or *putrefactive fermentation*. We shall now consider these three sorts of fermentation, and their effects, a little more particularly.

These three sorts of fermentation may take place successively in the same subject; which proves them to be only three different degrees of fermentation, all proceeding from one and the same cause, rather than three distinct fermentations. These degrees of fermentation always follow the order in which we have here placed them.



C H A P. XIII.

Of the SPIRITUOUS FERMENTATION.

THE juices of almost all fruits, all saccharine vegetable matters, all farinaceous seeds and grains of every kind, being diluted with a sufficient quantity of water, are proper subjects of spirituous fermentation. If such liquors be exposed, in vessels slightly stopped, to a moderate degree of heat, they begin in some time to grow turbid; there arises insensibly a small commotion among their parts, attended with a hissing noise; this by little and little increases till the grosser parts appear, like little seeds or grains, moving to and fro, agitated among themselves, and thrown up to the surface. At the

same time air bubbles arise, and the liquor acquires a pungent, penetrating smell, occasioned by the very subtile vapours which exhale from it.

These vapours have never yet been collected, in order to examine their nature; and they are known only by their noxious effects. They are so actively pernicious, that if a man comes rashly into a close place, where large quantities of liquors are fermenting, he suddenly drops down and expires, as if he were knocked on the head.

When these several phenomena begin to go off, it is proper to stop the fermentation, if a very spirituous liquor be required: for if it be suffered to continue longer, the liquor will become acid, and from thence proceed to its last stage, that is, to putrefaction. This is done by stopping the containing vessels very close, and removing them into a cooler place. Then the impurities precipitate, and settling at the bottom leave the liquor clear and transparent: and now the palate discovers that the sweet saccharine taste it had before fermentation is changed to an agreeable pungency which is not acid.

Liquors thus fermented are in general called *wines*: for though in common life that word properly signifies the fermented juice of grapes only, and particular names are given to the fermented juices of other vegetable substances; as that obtained from apples is called *cyder*; and that made from malt is called *beer*: yet in chymistry it is of use to have one general term denoting every liquor that has undergone this first degree of fermentation.

By distillation we draw from wine an inflammable liquor, of a yellowish white colour, light, and of a penetrating, pleasant smell. This liquor is the truly spiritous part of the wine, and the product of fermentation. That which comes off in the first distillation is commonly loaded with much
phlegm

phlegm and some oily parts, from which it may be afterwards freed. In this state it goes by the name of *brandy*; but when freed from these heterogeneous matters by repeated distillations, it becomes still clearer, lighter, more fragrant, and much more inflammable, and then is called *spirit of wine*, and *rectified spirit of wine*, or an *ardent spirit*, if considerably purified. The properties which distinguish an ardent spirit from all other substances are its being inflammable; its burning and consuming entirely, without the least appearance of smoke or fuliginosity; its containing no particles reducible to coal; and its being perfectly miscible with water. Ardent spirits are lighter and more volatile than any of the principles of the mixts from which they were produced, and consequently more so than the phlegm, the acid, and the oil of which they themselves consist. This arises from a particular disposition of these principles, which are in a singular manner attenuated by fermentation, and thereby rendered more susceptible of expansion and rarefaction.

Ardent spirits are supposed to be the natural solvents of oils and oily matters. But it is very remarkable that they dissolve essential oils only, without touching the fat of animals, or the fat oils obtained from vegetables by expression; yet when these oils have once undergone the action of fire, they become soluble in spirit of wine, and even acquire a new degree of solubility every time they are distilled. It is not so with essential oils, which can never be rendered more soluble in ardent spirits than they are at first: and are so far from acquiring a new degree of solubility every time they are distilled, that on the contrary they even in some measure lose that property by repeated rectifications.

I have taken some pains to find out the causes of these singular effects, and the result of my enquiries is published among the memoirs of the

Academy of Sciences for the year 1745. I there-
in consider ardent spirits as consisting of an oil, or
at least a phlogiston, mixed with a portion of
water, in which it is rendered soluble by means of
an acid. This being laid down, I shew that the
inability of spirit of wine to dissolve some oils must
be imputed to its aqueous part, in which oils are
not naturally soluble without the intervention of
a salt: and that the power which this spirit exerts in
dissolving other oils with ease, such as essential oils,
must, in all probability, be owing to this, that in
these oils it meets with the necessary saline medium,
that is, with an acid, which numberless experi-
ments shew they actually contain.

On the other hand, I there prove that the acid
in essential oils is superabundant, and in some sort
foreign to their nature, or that is but slightly con-
nected with them, and in part deserts them every
time they are distilled; which renders them less
soluble after every new rectification; whereas,
on the contrary, the fat expressed in their na-
tural state give not the least sign of acidity; but
the action of fire upon them discovers an acid
which was not perceived before. Hence I con-
jecture that these oils contain no more acid than is
just necessary to constitute them oils; that this acid
is intimately blended with their other component
parts; that it is so sheathed and entangled by these
parts as to be incapable of exerting any of its pro-
perties; and that on this account these oils in their
natural state are not soluble in spirit of wine: but
that the disposition of their parts being gradually
changed by the fire, and their acid, being by that
means set more and more at liberty, at length re-
covers its properties, and particularly that of ren-
dering the oily parts soluble in an aqueous men-
struum: and hence it follows that the fat oils be-
come so much the more soluble in spirit of wine
the oftener they are exposed to the action of fire.

Spirit

Spirit of wine doth not dissolve fixed alkalis ; or at least it takes up but a very small quantity thereof ; and hence ardent spirits may be freed from much of their phlegm by means of these salts thoroughly dried : for as they strongly imbibe moisture, and have even a greater affinity than ardent spirits with water, if a mixed alkali, well exsiccated, be mixed with spirit of wine that is not perfectly dephlegmated, the alkali immediately attracts its superfluous moisture, and is thereby resolved into a liquor, which, on account of its gravity, descends to the bottom of the vessel. The spirit of wine, which swims at top, is by this means as much dephlegmated, and as dry, as if it had been rectified by several distillations. As it takes up some alkaline particles in this operation, it is thereby qualified to dissolve oily matters with the greater facility. When rectified in this manner it is called *alcoholized spirit of wine*.

Yet spirit of wine, even when rectified to an alcohol, is not capable of dissolving all oily matters. Those named gums will by no means enter into any sort of union therewith ; but it readily dissolves most of those which are known by the appellation of resins. When it has dissolved a certain proportion of resinous particles it acquires a greater consistence, and forms what is called a *spirit-varnish*, or a *drying varnish*, because it soon dries. This varnish is subject to be damaged by water. Many sorts thereof are prepared, differing from each other according to the different resins employed, or the proportions in which they are used. Most of these varnishes are transparent and colourless.

Such bitumens or resins, as spirit of wine will not touch, are dissolved in oils by means of fire, and then form another kind of varnish, which water does not hurt. These varnishes are usually coloured,

loured, and require much longer time to dry than the spirit-varnishes; they are called *oil-varnishes*.

Spirit of wine hath a much greater affinity with water than with oily matters; and therefore if a solution of any oil or resin in spirit of wine be mixed with water the liquor immediately grows turbid, and acquires a whitish milky colour, owing entirely to the oily parts being separated from the spirituous menstruum by the accession of water, and too finely divided to appear in their natural form. But if the liquor stand some time quiet, several of these particles unite together, and gradually acquire a bulk sufficient to render them very perceptible to the eye.

Acids have an affinity with spirit of wine, and may be combined with it. By this union they lose most of their acidity, and on that account are said to be *dulcified*. But as these combinations of acids, especially of the vitriolic acid, with spirit of wine furnish some new productions of very singular properties, and as an examination thereof may throw much light on the nature of ardent spirits, it will not be amiss to take notice of them in this place, and consider each of them particularly.

One part of highly concentrated oil of vitriol being mixed with four parts of well dephlegmated spirit of wine, there arises immediately a considerable ebullition and effervescence, attended with great heat, and abundance of vapours, which smell pleasantly, but are hurtful to the lungs. At the same time is heard a hissing like that produced by a piece of red-hot iron plunged into water. Indeed it is proper to mix the liquors very gradually; for otherwise the vessels in which the operation is performed will be in great danger of breaking.

If the two liquors thus mixed be distilled with a very gentle heat, there rises first a spirit of wine of a most penetrating and grateful odour: when a-
bout

about half thereof is come over, what follows has a quicker and more sulphureous smell, and is also more loaded with phlegm. When the liquor begins to boil a little, there comes off a phlegm which smells very strong of sulphur, and grows gradually more acid. On this phlegm floats a small quantity of a very light and very limpid oil. In the still there remains a thick, blackish substance, somewhat like a resin or bitumen. From this substance may be separated a good deal of a vitriolic but sulphureous acid. When that is extracted, there remains a black mass like a charred coal, which being put into a crucible, and exposed to a violent heat, leaves a small portion of earth, very fixed and even vitrifiable.

By rectifying the ardent spirit, which came over in distilling the abovementioned mixture, a very singular liquor is obtained, which differs essentially both from oils and from ardent spirits, though in certain respects it resembles them both. This liquor is known in chymistry by the name of *æther*, and its chief properties are as follow.

Æther is lighter, more volatile, and more inflammable, than the most highly rectified spirit of wine. It quickly flies off when exposed to the air, and suddenly catches fire when any flame approaches it. It burns like spirit of wine without the least smoke, and consumes entirely without leaving the smallest appearance of a coal or of ashes. It dissolves oils and oily matters with great ease and rapidity. These properties it has in common with an ardent spirit. But it resembles an oil in that it is not miscible with water; and this makes it essentially different from spirit of wine, the nature of which is to be miscible with all aqueous liquors.

Another very singular property of *æther* is its great affinity with gold, exceeding even that of *aqua regis*. It does not indeed dissolve gold when in a mass, and in its metalline form: but if a small

quantity will unite wth about $\frac{1}{10}$ of quantity of *æther*.

quantity of æther be added to a solution of gold in *aqua regis*, and the whole shaken together, the gold separates from the *aqua regis*, joins the æther, and remains dissolved therein.

The reason of all the phenomena above-mentioned, resulting from the mixture of spirit of wine with oil of vitriol, is founded on the great affinity between this acid and water. For, if the vitriolic acid be weak, and as it were over-dosed with watery parts, neither oil nor æther can be obtained by means thereof: but when highly concentrated, it attracts the aqueous parts very powerfully; and therefore being mixed with spirit of wine lays hold of most of the water contained in it, and even robs it of some portion of that which is essential to its nature, and necessary to constitute it spirit of wine: whence it comes to pass that a certain quantity of the oily particles in its composition being separated from the watery particles, and so brought nearer to each other, they unite and assume their natural form; and thus the oil that swims at top of the sulphureous phlegm is produced.

The vitriolic acid moreover thickens and even burns some of this oil; and hence comes the bituminous residuum left at the bottom of the still, which looks like the result of a vitriolic acid combined with common oil. Lastly, the vitriolic acid becomes sulphureous, as it always doth when united with oily matters, and also very aqueous, on account of the quantity of phlegm which it attracts from the spirit of wine.

* Æther may be considered as a spirit of wine exceedingly dephlegmated, even to such a degree that its nature is thereby changed; so that the few aqueous particles left in it are not sufficient to dissolve the oily particles and keep them asunder; which therefore being now much nearer to one another than in common spirit of wine, the liquor hath lost its property of being miscible with water.

*False Theory, part of y > certainly unites Spirit
with y & V, as ether may be made with acids
that have no attractⁿ for V. -*

Spirit of nitre well dephlegmated, and combined with spirit of wine, presents likewise some very singular appearances.

First, in the very instant of its mixture with spirit of wine, it produces a greater and more violent effervescence than the vitriolic acid occasions.

Secondly, this mixture, without the help of distillation, and only by stopping the bottle in which the liquors are contained, affords a sort of æther, produced probably by the vapours which ascend from, and swim at top of the mixture. This is a very singular liquor. Dr. Navier was the first that took notice of it, and gave a description thereof, which may be seen in the memoirs of the academy of sciences.

Thirdly, some authors pretend that, by distilling the mixture under consideration, an oil is obtained greatly resembling that which, as we observed above, rises from spirit of wine combined with the vitriolic acid: others again deny this. For my part, I believe the thing depends on the different concentration of the spirit of nitre, as well as on the quality of the spirit of wine, which is sometimes more sometimes less oily.

Fourthly, the two liquors we are speaking of, being intimately mixed by distillation, form a liquor slightly acid, used in medicine, and known by the name of *Sweet* or *Dulcified spirit of nitre*: a very proper name, seeing the nitrous acid, by uniting with the spirit of wine, actually loses almost all its acidity and corrosive quality.

Fifthly and lastly, when the distillation is finished, there remains in the bottom of the vessel a thick, blackish substance, nearly resembling that which is found after distilling oil of vitriol and spirit of wine.

Spirit of salt hath likewise been combined with spirit of wine; but it does not unite therewith so easily or so intimately as the two acids above mentioned.

tioned. To mix them thoroughly, the spirit of salt must be highly concentrated, and smoking, and moreover the assistance of the still must be called in. Some authors pretend that from this mixture also a small quantity of oil may be obtained; which probably happens when the liquors have the qualities above specified. The marine acid likewise, by uniting with spirit of wine, loses most of its acidity; on which account it is in like manner called *Sweet or Dulcified spirit of salt*. A thick residuum is also found here after distillation.

an other may be made wth y^e acid



C H A P. XIV.

Of the Acetous fermentation.

1. Of vinegar. 2. Of tartar.

BESIDES an ardent spirit, wine affords a great deal of water, oil, earth, and a sort of acid which shall be considered presently. When the spiritous part is separated from these other matters, they undergo no further change. But if all the constituent parts of wine remain combined together, then, after some time, shorter or longer as the degree of heat in which the wine stands is greater or less, the fermentation begins afresh, or rather arrives at its second stage. The liquor once more grows turbid, a new intestine motion arises, and after some days it is found changed into an acid; which, however, is very different from those hitherto treated of. The liquor then takes the name of *Vinegar*. The acetous fermentation differs from the spiritous, not only in its effect, but also in several of its concomitant circumstances. Moderate motion is

of service to this, whereas it obstructs the spirituous; and it is attended with much more warmth than the spirituous. The vapours it produces are not noxious, like those of fermenting wine. Lastly, vinegar deposits no tartar, even when the wine employed in this operation is quite new, and hath not had time to discharge its tartar: instead of tartar vinegar deposits a viscid matter which is very apt to putrify.

It must be observed that wine is not the only substance that is susceptible of the acetous fermentation: for several vegetable and even animal matters, which are not subject to the spirituous fermentation, turn sour before they putrify. But as vinous liquors possess in a very eminent degree the property of being susceptible of the acetous fermentation, and likewise of producing the strongest acids that can result from such fermentation, their acid shall be more particularly considered in this place.

§. I. Of VINEGAR.

If wine, which has gone through this second stage of fermentation, be distilled, instead of an ardent spirit, only an acid liquor is obtained, which is called *Distilled vinegar*.

This acid has the same properties as the mineral acids of which we have already treated; that is, it unites with alkaline sorts, absorbent earths, and metallic substances, and therewith forms neutral saline combinations.

Its affinity with these substances observes the same order as that observed by the mineral acids with regard to the same substances; but in general it is weaker; that is, any mineral acid is capable of expelling the acid of vinegar out of all matters with which it is united.

Vinegar hath likewise a greater affinity than sulphur.

phur with alkalis: whence it follows that it is capable of decomposing that combination of sulphur with an alkali called *liver of sulphur*, and of precipitating the sulphur it contains.

The acid of vinegar is always clogged with a certain proportion of oily parts, which greatly weaken it, and deprive it of much of its activity; and for this reason it is not near so strong as the mineral acids, which are not entangled with any oil. By distillation, indeed, it may be freed from this oil, and at the same time from the great quantity of water which in a manner suffocates it, and by that means may be brought much nearer to the nature of the mineral acids: but this attempt hath not yet been prosecuted with the assiduity it deserves. Besides distillation, there is another way of freeing vinegar from a good deal of its phlegm; and that is, by exposing it to a hard frost, which readily congeals the watery part into ice, while the acid retains its fluidity.

Vinegar, saturated with a fixed alkali, forms a neutral oily salt, of a dark colour, which is semivolatile, melts with a very gentle heat, flames when thrown upon burning coals, and dissolves in spirit of wine, of which, however, it requires six parts to complete the solution. This solution being evaporated to dryness leaves a matter in the form of leaves lying on each other; on which account it hath obtained the name of *Terra foliata*. The same foliated matter will be obtained, though the salt be not previously dissolved in spirit of wine; but not so readily. This salt is also called *Regenerated tartar*. Under the head of tartar we shall see the reason of these different appellations. Regenerated tartar is also in some degree capable of crystallizing: for this purpose a solution thereof in water must be slowly evaporated to the consistence of a syrup, and then suffered to stand quiet in a cool place; by which means it will shoot into clusters

clusters of crystals, lying one upon another, not unlike the feathers on a quill.

With vinegar and several absorbent earths, such as calcined pearls, coral, shells of fish, &c. are also formed neutral saline compounds, each of which takes the name of the particular earth employed in its composition.

Vinegar perfectly dissolves lead, and converts it into a neutral metallic salt, which shoots into crystals, and has a sweet saccharine taste. This compound is called *Sugar of lead*, or *sal Saturni*.

If lead be exposed to the bare vapour of vinegar, it will be thereby corroded, calcined, and converted into a white matter much used in painting, and known by the name of *Ceruse*; or, when it is finer than ordinary, *White lead*.

Vinegar corrodes copper likewise, and converts it into a beautiful green rust, which also is used in painting, and distinguished by the name of *Verdegris*. However, vinegar is not commonly employed to make verdegris: for this purpose they use wine, or the rape of wine, from which fire extricates an acid analogous to that of vinegar.

In treating of the several substances which constitute wine we mentioned an acid matter, but did not then enter into a particular examination thereof; because as that matter greatly resembles the acid of vinegar, we thought it more proper to defer the consideration of its properties till we had treated of the acetous fermentation, and its effects.

§. II. Of TARTAR.

This substance is a saline compound, consisting of earthy, oily, and especially acid parts. It is found in the form of crusts, adhering to the inner sides of vessels in which wines have stood for some time, particularly acid wines, such as those of Germany.

Tartar derives its origin from the superabundant quantity of acid contained in the juice of the grape. This superfluous acid, being more than is requisite to constitute the ardent spirit, unites with some of the oil and earth contained in the fermented liquor, and forms a kind of salt; which for some time continues suspended in that liquor, but, when the wine stands undisturbed in a cool place, is deposited, as hath been said, on the sides of the cask.

Tartar in this state contains many earthy parts, which are superfluous, and foreign to its nature. From these it may be freed by boiling it repeatedly with a sort of earth found in the neighbourhood of Montpellier, as may be seen in the Memoirs of the Academy of Sciences.

When it is purified, there appears on the surface of the liquor a sort of white crystalline pellicle, which is skimmed off as it forms. This matter is called *Cream of Tartar*. The same liquor which produces this cream, and in which the purified tartar is dissolved, being set to cool, yields a great number of white semi-transparent crystals, which are called *Crystals of Tartar*. The cream and the crystals of Tartar are therefore no other than purified Tartar, and differ from each other in their form only.

Though the crystals of Tartar have every appearance of a neutral salt, yet they are far from being such; for they have all the properties of a true acid, which scarce differs from that of vinegar, except that it contains less water, and more earth and oil; to which it owes its solid form, as well as its property of not being soluble in water without much difficulty: for a very great quantity of water is requisite to keep the crystals of Tartar in solution; and it must moreover be boiling hot; otherwise as soon as it cools most of the Tartar dissolved

it separates from the liquor, and falls to the bottom in the form of a white powder.

Tartar is decomposed by calcination in the open fire. All its oily parts are consumed or dissipated in smoke, together with most of its acid. The other part of its acid, uniting intimately with its earth, forms a very strong and very pure fixed alkali, called *Salt of Tartar*.

It will be shewn in its proper place that almost every vegetable matter, as well as Tartar, leaves a fixed alkali in its ashes: yet Tartar has these peculiar properties; first, it assumes an alkaline character even when burnt or calcined in close vessels, whereas other substances acquire it only by being burnt in the open air; secondly, the alkali of Tartar is stronger and more saline than almost any that is obtained from other matters.

This alkali, when thoroughly calcined, powerfully attracts the moisture of the air, and melts into an unctuous alkaline liquor, improperly called *Oil of Tartar per deliquium*. This is the alkali generally used in making the *Terra foliata*, mentioned under the head of vinegar; for which reason this combination is called *Terra foliata Tartari*; a name suitable enough. But the same cannot be said of the other name, *regenerated Tartar*, which is also given it. 'Tis true that on this occasion an oily acid is restored to the earth of the tartar, analogous to that of which the fire had deprived it: but the compound thence resulting is a neutral salt which very readily dissolves in water; whereas Tartar is manifestly acid, and not soluble, or at least hardly soluble, in water.

Crystals of Tartar combined with alkali of Tartar produce a great effervescence while they are mixing, as all acids usually do; and if the combination be brought exactly up to the point of saturation, a perfectly neutral salt is formed, which shoots into crystals, and easily dissolves in water;

and this hath procured it the name of *Soluble Tartar*. It is also called the *Vegetable Salt*, as being obtained from vegetables only; and again, *Tartarised Tartar*, because it consists of the acid and the alkali of Tartar combined together.

Crytals of Tartar combined with alkalis procured from the ashes of maritime plants, such as Soda, which alkalis resemble the basis of sea-salt, form likewise a neutral salt, which crytallizes well, and dissolves easily in water. This salt is another sort of soluble Tartar. It is called *Saignette's salt*, from the inventor's name.

Both the vegetable salt and Saignette's salt are gently purgative soaps, and much used in medicine.

Tartar likewise dissolves the absorbent earths, as lime, chalk, &c. and with them forms neutral salts which are soluble in water *. It even attacks metallic bodies, and when combined with them becomes soluble. A soluble Tartar for medical use is prepared with crytals of tartar and iron: the metallic salt thereby produced hath the name of *Chalybeated soluble Tartar*. This salt attracts the moisture of the air, and is one of those which do not crytallize.

Crytallized tartar acts also upon several other metallic substances: for instance, it dissolves the regulus, liver, and glass of antimony, and thence acquires an emetic quality: it is then called *Stibiated* or *Emetic Tartar*. It likewise dissolves lead, and therewith forms a salt, which, in the figure of its crytals, resembles tartarized tartar.

It is very extraordinary that tartar, which of itself is not soluble in water, should be soluble therein when become a neutral salt by uniting either with alkalis or with absorbent earths, or even with me-

* See Mr. Duhamel's essays on this subject in the Memoirs of the academy of sciences.

als. With respect to alkalis, indeed, it may be urged that, having themselves a great affinity with water, they communicate to tartar some of that facility with which they naturally unite therewith: but the same cannot be alledged concerning absorbent earths, and metallic substances, which water dissolves not at all, or at least with great difficulty, and in small quantity. This effect, therefore, must be attributed wholly to some change in the disposition of its parts which is to us unknown.

All the soluble tartars are easily decomposed by exposing them to a certain degree of heat. In distillation they yield the same principles which are obtained from tartar; and what remains fixed in the fire, after they are thoroughly burnt, is a compound of the alkali which tartar naturally produces, and of the alkaline or metallic substance with which it was converted into a neutral salt.

As crystal of tartar is the weakest of all acids, on account of the oily and earthy matters with which it is combined, soluble tartars are decomposed by all the acids; by any of which crystal of tartar may be separated from the substance that serves it for a basis and renders it a neutral salt.

The other acids which are procured from vegetables, and even those which are obtainable from some animal substances, may all be referred to and compared with either vinegar or tartar, according to the quantities of oil or earth with which they are combined.

After all, these acids have not yet been thoroughly examined. There is great reason to think that they are no other than the mineral acids, which in passing through the bodies of vegetables, and even of animals, undergo a considerable change, especially by contracting an union with oily matters. For, as we said before in treating of vinegar, by freeing them from their oil they are brought very near to the nature of mineral acids: and

and so likewise the mineral acids acquire many of the properties of vegetable acids by being combined with oils.



C H A P. XV.

Of the PUTRID FERMENTATION, *or* PUTREFACTION.

EVery body which hath gone through the two stages of fermentation above-described, that is, the spirituous and the acetous fermentation, being left to itself in a due degree of warmth, which varies according to the subject, advances to the last stage of fermentation; that is, to putrefaction.

It is proper to observe, before we go any further, that the converse of this proposition is not true; that is, it is not necessary that a body should successively pass through the spirituous and the acetous fermentation, before it can arrive at the putrid; but that, as certain substances fall into the acetous without having gone through the spirituous fermentation, so others begin to putrify without having undergone either the spirituous or the acetous fermentation, of which last kind are, for instance, most animal substances. When therefore we represented these three sorts of fermentation as three different degrees or stages of one and the same fermentation, we supposed it to be excited in a body susceptible of fermentation in its full extent.

However, there is still room to think that every substance which is capable of fermenting always passes necessarily through these three different stages; but that the substances most disposed thereto pass with such rapidity through the first, and even the

the second, that they arrive at the third before our senses can perceive the least signs of either of the two former. This opinion is not destitute of probability; yet it is not supported by proofs sufficiently strong and numerous to compel our assent.

When a body is in a putrefying state it is easy to discover, (as in the two sorts of fermentation already treated of) by the vapours which rise from it, by the opacity which invades it, if a pellucid liquor, and frequently even by a greater degree of heat than is found in the two other sorts of fermentation, that an intestine motion is begun among its constituent parts, which lasts till the whole be entirely putrefied.

The effect of this intestine motion is in this, as in the two other sorts of fermentation, to break the union, and change the disposition, of the particles constituting the body in which it is excited, and to produce a new combination. This is brought about by a mechanism to which we are strangers, and concerning which nothing beyond conjectures can be advanced: but these we neglect, resolving to keep wholly to facts, as the only things in natural philosophy that are positively certain.

If, then, we examine a substance that has undergone putrefaction, we shall soon perceive that it contains a principle which did not exist in it before. If this substance be distilled, there rises first, by means of a very gentle heat, a saline matter which is exceedingly volatile, and affects the organ of smelling briskly and disagreeably. Nor is the aid of distillation necessary to discover the presence of this product of putrefaction: it readily manifests itself in most substances where it exists, as any one may soon be convinced by observing the different smell of fresh and of putrified urine; for the latter not only affects the nose, but even makes the eyes smart, and irritates them so as to draw tears from them in abundance.

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This saline principle which is the product of putrefaction, when separated from the other principles of the body which affords it, and collected by itself, appears either in the form of a liquor, or in that of a concrete salt, according to the different methods used to obtain it. In the former state it is called a *volatile urinous spirit*; and in the latter a *volatile urinous salt*. The qualification of urinous is given it, because, as was said, a great deal thereof is generated in putrified urine, to which it communicates its smell. It goes also by the general name of a *volatile alkali*, whether in a concrete or in a liquid form. The enumeration of its properties will shew why it is called an alkali.

Volatile alkalis, from whatever substance obtained, are all alike, and have all the same properties; differing only according to their degrees of purity. The volatile alkali, as well as the fixed, consists of a certain quantity of acid combined with and entangled by a portion of the earth of the mixt body from which it was obtained; and on that account it has many properties like those of a fixed alkali. But there is moreover in its composition a considerable quantity of a fat or oily matter, of which there is none in a fixed alkali; and on this account again there is a great difference between them. Thus the volatility of the alkali produced by putrefaction, which is the principal difference between it and the other kind of alkali whose nature it is to be fixed, must be attributed to the portion of oil which it contains: for there is a certain method of volatilizing fixed alkalis by means of a fatty substance.

Volatile alkalis have a great affinity with acids, unite therewith rapidly and with ebullition, and form with them neutral salts, which shoot into crystals, but differ from one another according to the kind of acid employed in the combination.

The neutral salts which have a volatile alkali for their

their basis are in general called *ammoniacal salts*, That whose acid is the acid of sea-salt is called *sal ammoniac*. As this was the first known, it gave name to all the rest. Great quantities of this salt are made in Egypt, and thence brought to us. They sublime it from the soot of cow's-dung, which is the fuel of that country, and contains sea-salt, together with a volatile alkali, or at least the materials proper for forming it; and consequently all the ingredients that enter into the composition of *sal ammoniac*. See the Memoirs of the Academy of Sciences.

The neutral salts formed by combining the acids of nitre and of vitriol with a volatile alkali are called, after their acids, *nitrous sal ammoniac*, and *vitriolic sal ammoniac*: the latter, from the name of its inventor, is also called Glauber's *secret sal ammoniac*.

A volatile alkali, then, has the same property as a fixed alkali with regard to acids: yet they differ in this, that the affinity of the former with acids is weaker than that of the latter: and hence it follows that any *sal ammoniac* may be decomposed by a fixed alkali, which will lay hold of the acid, and discharge the volatile alkali.

A volatile alkali will decompose any neutral salt which has not a fixed alkali for its basis; that is, all such as consist of an acid combined with an absorbent earth or a metallic substance. By joining with the acids in which they are dissolved, it disengages the earth or metallic substances, takes their place, and in conjunction with their acids, forms ammoniac salts.

Hence it might be concluded, that, of all substances, next to the phlogiston and the fixed alkalis, volatile alkalis have the greatest affinity with acids in general. Yet there is some difficulty in this matter: for absorbent earths, and several metallic substances, are also capable of decomposing

ing ammoniacal salts, discharging their volatile alkali, and forming new compounds by uniting with their acids. This might induce us to think that these substances have nearly the same affinity with acids.

But it is proper to observe, that a volatile alkali decomposes such neutral salts as have for their basis either an absorbent earth or a metallic substance, without the aid of fire; whereas absorbent earths or metallic substances will not decompose an ammoniacal salt, unless they be assisted by a certain degree of heat.

Now as all these matters are extremely fixed, at least in comparison with a volatile alkali, they have the advantage of being able to resist the force of fire, and so of acting in conjunction therewith; and fire greatly promotes the natural action of substances upon one another: whereas the volatile alkali in the ammoniacal salt, being unable to abide the force of fire, is compelled to desert its acid; and that so much the more quickly, as its affinity therewith is considerably weakened by the presence of an earthy or metallic substance, both of which have a greater affinity with acids.

These considerations oblige us to conclude, that volatile alkalis have a somewhat greater affinity, than absorbent earths and metallic substances, with acids.

Ammoniacal salts projected upon nitre in fusion make it detonate; and the nitrous salt ammoniac detonates by itself, without the addition of any inflammable matter. This singular effect evidently demonstrates the existence of an oily matter in volatile alkalis; for it is certain that nitre will never deflagrate without the concurrence, and even the immediate contact, of some combustible matter.

This oily substance is often found combined with volatile alkalis in such a large proportion as to disguise it, in some measure, and render it exceeding
foul.

foul. The salt may be freed from its superfluous oil by repeated sublimations; and particularly by subliming it from absorbent earths, which readily drink up oils. This is called the *rectification* of a volatile alkali. The salt, which before was of a yellowish or dirty colour, by being thus rectified becomes very white, and acquires an odour more pungent and less fetid than it had at first, that is, when obtained by one single distillation from a putrid substance.

It is proper to observe that the rectification of a volatile alkali must not be carried too far or repeated too often; for by that means it may be entirely decomposed at length; and particularly if an absorbent earth, and especially chalk, be employed for that purpose, the salt may be converted into an oil, an earth, and water.

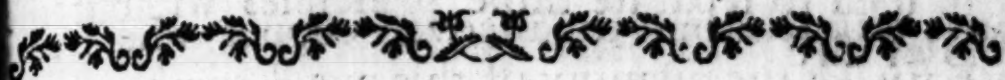
Volatile alkalis act upon several metallic substances, and particularly on copper; of which they make a most beautiful blue solution. On this property depends a pretty singular effect, which happens sometimes when we attempt, by means of a volatile alkali, to separate copper from any acid with which it is combined. Instead of seeing the liquor grow turbid, and the metal fall, both which generally happen when any alkali whatever is mixed with a metallic solution, we are surprised to observe the solution of copper, upon adding a volatile alkali, retain its limpidity, and let fall no precipitate; or at least if the liquor does grow turbid, it remains so but for a moment, and instantly recovers its transparency.

This is occasioned by adding such a quantity of volatile alkali as is more than sufficient fully to saturate the acid of the solution, and considerable enough to dissolve all the copper as fast as it is separated from the acid. On this occasion the liquor acquires a deeper blue than it had before; which arises from the property which volatile alkalis have

of giving this metal, when combined with them, a fuller blue than any other solvent can : hence we have a touchstone to discover copper wherever it is ; for let the quantity of this metal combined with other metals be ever so small, a volatile alkali never fails to discover it, by making it appear of a blue colour.

Though a volatile alkali be constantly the result of putrefaction, yet it must not therefore be imagined, that none can be produced by any other means ; on the contrary, most of those substances which contain the ingredients necessary to form it, yield no inconsiderable quantity thereof in distillation. Tartar, for example, which by being burnt in an open fire, is converted, as was shewn, into a fixed alkali, yields a volatile alkali when it is decomposed in close vessels ; that is, when it is distilled : because in this latter case the oily part is not dissipated or burnt, as it is by calcination in a naked fire, but has time to unite with some of the earth and acid of the mixt, in such a manner as to form a true volatile alkali.

To prove that on this occasion, as well as on all others, where unpetrified bodies yield a volatile alkali, this salt is the product of the fire, we need only observe, that in these distillations it never rises till after some part of the phlegm, of the acid, and even of the thick oil of the mixt, is come over ; which never is the case when it is formed beforehand in the body which is the subject of the operation, as it is in those which have undergone putrefaction : for this salt, being much lighter and more volatile than those other substances, rises of course before them in distillation.



C H A P. XVI.

A General View of CHYMICAL DECOMPOSITION.

1. The Analysis of Vegetable Substances. Emulsions.
2. The Analysis of Animal Substances.
3. The Analysis of Mineral Substances. Of the Pyrites. Of Ores.

THOUGH we have considered all the substances which enter into the composition of vegetables, animals, and minerals, whether as primary or as secondary principles, it will not be improper to shew in what order we obtain these principles from the several mixts; and especially from vegetables and animals, because they are much more complicated than minerals. This is called *analysing* a compound.

The method most commonly taken to decompose bodies is by applying to them successive degrees of heat, from the gentlest to the most violent, in appropriated vessels, so contrived as to collect what exhales from them. By this means the principles are gradually separated from each other; the most volatile rise first, and the rest follow in order, as they come to be acted on by the proper degree of heat: and this is called *distillation*.

But it being observed that fire, applied to the decomposition of bodies, most commonly alters their secondary principles very sensibly, by combining them in a different manner with each other, or even partly decomposing them, and reducing them

to their primitive principles; other means have been used to separate those principles without the help of fire.

With this view the mixts to be decomposed are forcibly compressed, in order to squeeze out of them all such parts of their substance as they will by this means part with; or else those mixts are for a long time triturated, either along with water, which carries off all their saline and saponaceous contents; or with solvents, such as ardent spirits, capable of taking up every thing in them that is of an oily or resinous nature.

We shall here give a succinct account of the effects of these different methods, as applied to the principal substances among vegetables and animals, and likewise to some minerals.

§. I. *The ANALYSIS of VEGETABLE SUBSTANCES.*

A vast many vegetable substances, such as kernels and seeds, yield by strong compression great quantities of mild, fat, unctuous oils, which are not soluble in ardent spirits: these are what we called *expressed oils*. They are also sometimes called *fat oils*, on account of their unctuousness, in which they exceed all other sorts of oil. As these oils are obtained without the aid of fire, it is certain that they existed in the mixt just as we see them, and that they are not in the least altered; which could not have been the case had they been obtained by distillation: for that never produces any oils but such as are acrid and soluble in spirit of wine.

Some vegetable matters, such as the rind of citrons, lemons, oranges, &c. also yield, only by being squeezed between the fingers, a great deal of oil. This spirits out in fine small jets, which being received upon any polished surface, such as a look-

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ing-glasses, run together and form a liquor that is a real oil.

But it must be carefully noted that this sort of oil, though obtained by expression only, is nevertheless very different from the oils mentioned before, to which the title of *expressed oils* peculiarly belongs: for this is far lighter and thinner; moreover, it retains the perfect odour of the fruit which yields it, and is soluble in spirit of wine; in a word, it is a true essential oil, but abounds so in the fruits which produce it, and is lodged therein in such a manner, occupying a vast number of little cells provided in the peel for its reception, that a very slight pressure discharges it; which is not the case with many other vegetables that contain an essential oil.

Succulent and green plants yield by compression a great deal of liquor or juice, which consists of most of the phlegm, of the salts, and a small portion of the oil and earth of the plant. These juices, being set in a cool place for some time, deposite saline crystals, which are a combination of the acid of the plant with part of its oil and earth, wherein the acid is always predominant. These salts, as is evident from the description here given, bear a great resemblance to the tartar of wine treated of above. They are called *Essential salts*; so that tartar might likewise be called the *Essential salt of wine*.

Dried plants, and such as are of a ligneous, or acid nature, require to be long triturated with water, before they will yield their essential salts. Trituration with water is an excellent way to get out of them all their saline and saponaceous contents.

A vegetable matter that is very oily yields its essential salt with much difficulty, if at all; because the excessive quantity of oil entangles the salt so that it cannot extricate itself or shoot into crystals.

Mr. Gerike, in his *Principles of Chymistry*, says, that

that if part of the oil of a plant be extracted by spirit of wine, its essential salt may be afterwards obtained with more ease and in greater quantity. This must be a very good method for such plants as have an excessive proportion of essential oil; but will not succeed if the essential salt be hindered from crystalizing by a redundancy of fat oil, because fat oils are not soluble in spirit of wine.

Essential salts are among those substances which cannot be extracted from mixts by distillation: for the first impression of fire decomposes them.

Though the acid which predominates in the essential salts of plants, be most commonly analogous to the vegetable acid, properly so called, that is, to the acid of vinegar and tartar, which is probably no other than the vitriolic acid disguised; yet it sometimes differs therefrom, and somewhat resembles the nitrous or the marine acid. This depends on the places where the plants grow which produce these salts: if they be maritime plants, their acid is akin to the acid of sea-salt; if on the contrary they grow upon walls, or in nitrous grounds, their acid is like that of nitre. Sometimes one and the same plant contains salts analogous to all the three mineral acids; which shews that the vegetable acids are no other than the mineral acids variously changed by circulating through plants.

Liquors containing the essential salts of plants being evaporated by a gentle heat to the consistence of honey, or even further, are called *Extracts*. Hence it is plain, that an extract is nothing but the essential salt of a plant, combined with some particles of its oil and earth, that remained suspended in the liquor, and are now incorporated by evaporation.

Extracts of plants are also prepared by boiling them long in water, and then evaporating some part of it. But these extracts are of inferior virtue; be-

cause the water causes the essential salt to be dissolved in the water, and the water is then evaporated off.

cause the fire dissipates many of the oily and saline parts.

EMULSIONS.

Substances which abound much in oil, being bruised and triturated with water for some time, afford a liquor of an opaque dead-white colour, like milk. This liquor consists of such juices as the water is capable of dissolving, together with a portion of the oil, which being naturally indissoluble in water, is only divided and dispersed in the liquor, the limpidity whereof is by that means destroyed. This sort of oily liquor, in which the oil is only divided, not dissolved, is called an *Emulsion*. The oily particles in emulsions spontaneously separate from the water, when left at rest, and uniting into greater masses rise, on account of their lightness, to the surface of the liquor, which by that means recovers a degree of transparency.

If vegetables abounding in essential oils and resins be digested in spirit of wine, the menstruum takes up these oily matters, as being capable of dissolving them; and they may afterwards be easily separated from it by the affusion of water. The water, with which spirit of wine has a greater affinity than with oily matters, separates them by this means from their solvent, agreeably to the common laws of affinities.

Without the help of fire scarce any thing, besides the substances already mentioned, can be obtained from a plant: but by the means of distillation we are enabled to analyze them more completely. In prosecuting this method of extracting from a plant the several principles of which it consists, the following order is to be observed.

A plant being exposed to a very gentle heat, in a distilling vessel set in the *balneum mariæ*, yields a water which retains the perfect smell thereof. Some Chymists,

Chymists, and particularly the illustrious Boerhaave, have called this liquor the *Spiritus rector*. The nature of this odoriferous part of plants is not yet thoroughly known; because it is so very volatile that it is difficult to subject it to the experiments necessary for discovering all its properties.

If instead of distilling the plant in the *balneum mariae*, it be distilled over a naked fire, with the precaution of putting a certain quantity of water into the distilling vessel along with it, to prevent its suffering a greater heat than that of boiling water, all the essential oil contained in that plant will rise together with that water, and with the same degree of heat.

On this occasion it must be observed that no essential oil can be obtained from a plant after the *Spiritus rector* hath been drawn off; which gives ground to think that the volatility of these oils is owing to that spirit.

The heat of boiling water is also sufficient to separate from vegetable matters the fat oils which they contain. That, however, is to be done by the way of decoction only, and not by distillation: because though these oils will swim on water, yet they will not rise in vapours without a greater degree of heat.

When the essential oil is come over, if the plant be exposed to a naked fire, without the addition of water, and the heat be increased a little, a phlegm will rise that gradually grows acid; after which, if the heat be increased as occasion requires, there will come over a thicker and heavier oil; from some a volatile alkali; and last of all, a very thick, black, empyreumatic oil.

When nothing more rises with the strongest degree of heat, there remains of the plant a mere coal only, called the *Caput mortuum*, or *Terra damnata*. This coal when burnt falls into ashes, which

which being lixiviated with water, give a fixed alkali.

It is observable that in the distillation of plants which yield an acid and a volatile alkali, these two salts are often found quite distinct and separate in the same receiver; which seems very extraordinary, considering that they are naturally disposed to unite, and have a great affinity with one another. The reason of this phenomenon is that they are both combined with much oil, which embarrasses them so that they cannot unite to form a neutral salt, as they would not fail to do were it not for that impediment.

All vegetables, except such as yield a great deal of volatile alkali, being burnt in an open fire, and so as to flame, leave in their ashes a large quantity of an acrid, caustic, fixed alkali. But if care be taken to smother them, so as to prevent their flaming while they burn, by covering them with something that may continually beat down again what exhales, the salt obtained from their ashes will be much less acrid and caustic; the cause whereof is, that some part of the acid and oil of the plant being detained in the burning, and stopped from being dissipated by the fire, combines with its alkali. These salts crystallize, and being much milder than the common fixed alkalis, may be used in medicine, and taken internally. They are called *Tachenius's salts*, because invented by that chymist.

Marine plants yield a fixed alkali analogous to that of sea-salt. As for all other plants or vegetable substances, the fixed alkalis obtained from them, if rightly prepared and thoroughly calcined, are all perfectly alike, and of the very same nature.

The last observation I have to make on the production of fixed alkalis is, that if the plant you intend to work upon be steeped or boiled in water before you burn it, a much smaller quantity of salt will

will be obtained from it ; nay, it will yield none at all, if repeated boilings have robbed it entirely of those saline particles which must necessarily concur with its earth to form a fixed alkali.

§. II. *The ANALYSIS of ANIMAL SUBSTANCES.*

Succulent animal substances, such as new-killed flesh, yield by expression a juice or liquid, which is no other than the phlegm, replete with all the principles of the animal body, except the earth, of which it contains but little. The hard or dry parts, such as the horns, bones, &c. yield a similar juice, by boiling them in water. These juices become thick, like a glue or jelly, when their watery parts are evaporated ; and in this state they are true extracts of animal matters. These juices afford no crystals of essential salt, like those obtained from vegetables, and shew no sign either of an acid or an alkali.

Great part of the oil which is in the flesh of animals may be easily separated without the help of fire ; for it lies in a manner by itself : it is commonly in a concrete form, and is called *fat*. This oil somewhat resembles the fat oils of vegetables ; for like them it is mild, unctuous, indissoluble in spirit of wine, and is subtilized and attenuated by the action of fire. But there is not in animals, as in vegetables, any light essential oil, which rises with the heat of boiling water ; so that, properly speaking, animals contain but one sort of oil.

Few animal substances yield a perceptible acid. Ants and bees are almost the only ones from which any can be obtained : And indeed the quantity they yield is very small, as the acid itself is extremely weak.

The reason thereof is, that as animals do not draw their nourishment immediately from the earth, but feed wholly either on vegetables or on the flesh
of

of other animals, the mineral acids, which have already undergone a great change by the union contracted between them and the oily matters of the vegetable kingdom, enter into a closer union and combination with these oily parts while they are passing through the organs and strainers of animals; whereby their properties are destroyed, or at least so impaired that they are no longer sensible.

Animal matters yield in distillation, first, a pelegm, and then, on increasing the fire, a pretty clear oil, which gradually becomes thicker, blacker, more fetid, and empyreumatic. It is accompanied with a great deal of volatile alkali; and if the fire be raised and kept up till nothing more comes over, there will remain in the distilling vessel a coal like that of vegetables; except that when it is reduced to ashes, no fixed alkali, or at least very little, can be obtained from them, as from the ashes of vegetables. This arises from hence that, as we said before, the saline principle in animals being more intimately united with the oil than it is in plants, and being consequently more attenuated and subtilized, is too volatile to enter into the combination of a fixed alkali; on the contrary it is more disposed to join in forming a volatile alkali, which on this occasion does not rise till after the oil, and therefore must certainly be the production of the fire. It must be observed, that all we have hitherto said concerning the analysis of bodies must be understood of such matters only as have not undergone any sort of fermentation.

The chyle and the milk of animals which feed on plants still retain some likeness to vegetables; because the principles of which these liquors are composed have not gone through all the changes which they must suffer before they enter into the animal combination.

Urine

Urine and sweat are excrementitious aqueous liquors, loaded chiefly with the saline particles which are of no service towards the nourishment of the animal, but pass through its strainers without receiving any alteration; such as the neutral salts which have a fixed alkali for their basis, and particularly the sea-salt, which happens to be in the food of animals, whethether it exist therein naturally, as it does in some plants, or whether the animals eat it to please their palates.

The saliva, the pancreatic juice, and especially the bile, are saponaceous liquors, that is, they consist of saline and oily particles combined together: so that being themselves dissolved in an aqueous liquor, they are capable of dissolving likewise the oily parts, and of rendering them miscible with water.

Lastly, the blood being the receptacle of all these liquors partakes of the nature of each, more or less in proportion to the quantity thereof which it contains.

§. III. *The* ANALYSIS of MINERAL SUBSTANCES.

Minerals differ greatly from vegetables, and from animals; they are not near so complex as those organized bodies, and their principles are much more simple; whence it follows, that these principles are much more closely connected, and that they cannot be separated without the help of fire; which not having on their parts the same action and the same power as on organized bodies, hath not the same ill effect on them; I mean the effect of changing their principles, or even destroying them intirely.

I do not here speak of pure, vitrifiable, or refractory earths; of mere metals, and semi-metals; of pure acids; or even of their simplest combinations,

tions, such as sulphur, vitriol, alum, sea-salt; of all these we have said enough.

We are now to treat of bodies that are more complex, and therefore more susceptible of decomposition. These bodies are compound masses, or combinations of those above-mentioned; that is, metallic substances as they are found in the bowels of the earth, united with several sorts of sand, stones, earths, semi-metals, sulphur, &c. When the metallic matter is combined with other matters, in such a proportion to the rest that it may be separated from them with advantage and profit, these compounds are called *ores*: When the case is otherwise, they are called *pyrites*, and *Marcasites*; especially if sulphur or arsenic be predominant therein, which often happens.

In order to analyse an ore, and get out of it the metal it contains, the first step is to free it from a great deal of earth and stones, which commonly adhere to it very slightly and superficially. This is effected by pounding the ore, and then washing it in water to the bottom of which the metalline parts presently sink, as being the heaviest, while the small particles of earth and stone remain suspended some time longer.

Thus the metallic part is left combined with such matters only as are most intimately complicated with it. These substances are most commonly sulphur and arsenic. Now as they are much more volatile than other mineral matters, they may be dissipated in vapours, or the sulphur may be consumed, by exposing the ore which contains them to a proper degree of heat. If the sulphur and arsenic be desired by themselves, the fumes thereof may be caught and collected in proper vessels and places. This operation is called *roasting an ore*.

The metal thus depurated is now fit to be exposed to a greater force of fire, capable of melting it.

On this occasion the semi-metals and the imperfect metals require the addition of some matter abounding in phlogiston, particularly charcoal-dust; because these metallic substances lose their phlogiston by the action of the fire, or of the fluxes joined with them; and therefore, without this precaution would never acquire either the splendour or the ductility of a metal. By this means the metallic substance is more accurately separated from the earthy and stony parts, of which some portion always remains combined therewith till it is brought to fusion. For, as we observed before, a metallic glass or calx only will contract an union with such matters; a metal possessed of its phlogiston and metalline form being utterly incapable thereof.

We took notice of the cause of this separation above, where we shewed that a metal possessed of its phlogiston and metalline form will not remain intimately united with any calcined or vitrified matter, not even with its own calx or glass.

The metal therefore, on this occasion, gathers into a mass, and lies at the bottom of the vessel, as being most ponderous; while the heterogeneous matters float upon it in the form of a glass, or a semi-vitrification. These floating matters take the name of *scoria*, and the metalline substance at bottom is called the *regulus*.

It frequently happens that the metalline regulus thus precipitated is itself a compound of several metals mixed together, which are afterwards to be separated. We cannot at present enter into a detail of the operations necessary for that purpose: they will appear in our Treatise of *Practical Chymistry*: But the principles on which they are founded may be deduced from what we have said above, concerning the properties of the several metals and of acids.

It is proper to observe, before we quit this subject, that the rules here laid down for analysing ores

ores are not absolutely general: for example, it is often adviseable to roast the ore before you wash it; for by that means some ores are opened, attenuated, and made very friable, which would cost much trouble and expence, on account of their excessive hardness, if you should attempt to pound them without a previous torrefaction.

It is also frequently necessary to separate the ore from part only of its stone; sometimes to leave the whole; and sometimes to add more to it, before you smelt it. This depends on the quality of the stone, which always helps to promote fusion when it is in its own nature fusible and vitrifiable. It is then called the *flour* of the ore: but of this we must say as we did of the preceding article; it is sufficient for our present purpose to lay down the fundamental principles on which the reason of every process is built; the description of the operations themselves being reserved for our Second Part.

We shall now give a succinct account of the principal ores and mineral bodies, contenting ourselves with just pointing out the particulars of which they severally consist.

Of the PYRITES.

The yellow Pyrites.

The yellow pyrites is a mineral consisting of sulphur, iron, an unmettallie earth, and frequently a little copper: the sulphur, which is the only one of these principles that is volatile, may be separated from the rest by sublimation: it usually makes a fourth, and sometimes a third, of the whole weight of these pyrites. The other principles are separated from one another by fusion and reduction with the phlogiston, which, by metallizing the ferruginous and cupreous earths, parts them from the unmetallie earth: for this earth vitrifies, and cannot

not afterwards continue united with metallic matters possessed of their metalline form, as hath been said before.

There is yet another way of decomposing the yellow pyrites, which is to let it lye till it effloresces, or begins to shoot into flowers; which is nothing but a sort of slow accension of the sulphur it contains. The sulphur being by this means decomposed, its acid unites with the ferruginous and cupreous parts of the pyrites, and therewith forms green and blue vitriols; which may be extracted by steeping in water the pyrites which has effloresced or been burnt, and then evaporating the lixivium to a pellicle; for by this means the vitriol will shoot into crystals.

Sometimes the pyrites contains also an earth of the same nature with that of allum: a pyrites of this sort, after flowering, yields alum as well as vitriol.

The White Pyrites.

The white pyrites contains much arsenic, a ferruginous earth, and an unmetallic earth. The arsenic being a volatile principle, may be separated by sublimation or distillation from the rest, which are fixed: and these again may be disjoined from each other by fusion and reduction, as was said in relation to the yellow pyrites.

The Copper Pyrites.

The copper pyrites contains sulphur, copper, and an unmetallic earth. A great deal thereof likewise holds arsenic, and its colour approaches more or less to orange, yellow, or white, according to the quantity of arsenic in it. It may be decomposed by the same means as the yellow and white pyrites.

Of

*Of ORES.**Of Gold Ores.*

Gold being constantly found in its metalline form, and never combined with sulphur and arsenic, its matrices are not, properly speaking, ores; because the metal contained in them is not mineralized. The gold is only lodged between particles of stone, earth, or sand, from which it is easily separated by lotion, and by amalgamation with quicksilver. The gold thus found is seldom pure, but is frequently alloyed with more or less silver, from which it is to be separated by quartation.

It is also very common to find gold in most ores of other metals or semi-metals, and even in the pyrites; but the quantity contained therein is generally so small, that it would not pay the cost of extracting it. However, if any should incline to attempt it, merely out of curiosity, it would be necessary to begin with treating these ores in the manner proper for separating their metalline part; then to cupel the metalline regulus so obtained; and, lastly, to refine it by quartation.

Of Silver Ores.

It is no rare thing to find silver, as well as gold, in its metalline form, only lodged in sundry earths and stony matters, from which it may be separated in the same manner as gold. But the greatest quantities of this metal are usually dug out of the bowels of the earth in a truly mineral state; that is, combined with different substances, and particularly with sulphur and arsenic.

Several silver ores are distinguished by peculiar characteristics, and are accordingly denoted by particular names. That which is called the vitreous

silver ore, is scarce any thing else but a combination of silver and sulphur. Another is known by the name of the *horny silver ore*, because when in thin plates it is semi-transparent: in this ore the silver is mineralized by sulphur and a little arsenic. The *red silver ore* is of the colour which its name imports, sometimes more, sometimes less vivid; and is chiefly composed of silver, arsenic, and sulphur: it also contains a little iron.

These three ores are very rich in silver: the first contains nearly three fourths of its weight, and the others about two thirds of theirs.

There is a fourth, called the *white silver ore*, which though it be heavier, is not so rich in silver, because it contains much copper. Many other minerals contain silver, yet are not, properly speaking, silver ores; because a much greater quantity of other metals than of silver is found in them.

When a silver ore is to be decomposed, in order to have the silver pure, or when silver is to be extracted out of any ore that contains it, the first thing to be done is to roast the ore, in order to clear it of the volatile minerals: and as silver cannot be had pure without the operation of the cupel, which requires more or less lead to be joined with it, it is usual to mix with the torrified silver ore a quantity of lead, proportioned to that of the heterogeneous matters combined with the silver, and to melt the whole together. Part of the added lead vitrifies during the fusion, and at the same time converts some of the heterogeneous matters also into glass, with which it forms a scoria that rises to the surface of the matter. The other part of the lead, with which the silver is mixed, falls to the bottom in the form of a regulus, which must be cupelled in order to have the silver pure.

Of Copper Ores.

Copper is much seldomer found in a metalline form than gold or silver: it is commonly in a mineral state: it is mineralized by sulphur and arsenic: almost all its ores contain also more or less iron; sometimes a little silver, or even gold, together with unmetallic earths and stones, as all ores do.

Most copper ores are of a beautiful green or blue, or else in shades blended of these two colours. The minerals called *mountain green*, and *mountain blue*, are true copper ores; not in the form of hard stones, like other ores, but crumbly and friable like earth.

Nevertheless there are several copper ores of different colours, as ash-coloured, whitish, and shaded with yellow or orange; which colours arise from the different proportions of arsenic, sulphur, and iron, which these ores contain.

In order to decompose a copper ore, and to extract the copper it contains, it is first of all to be freed from as many of its earthy stony, sulphureous and arsenical parts, as is possible, by roasting and washing; then what remains is to be mixed with a flux compounded of a fixed alkali and some inflammable matter; a little sea-salt is to be put over all, and the whole melted by a strong fire. The salts facilitate the fusion and scorification of the unmetallic matters, and therewith form a slag, which being the lightest rises to the surface. The metalline matters are collected below in the form of a shining regulus of copper; which, however, is not usually fine copper, but requires to be purified in the manner to be shewn in our second part.

In order to separate the copper from the unmetallic matters, it is absolutely necessary to melt its ore

ore along with inflammable substances abounding in phlogiston. For, as this metal is not possessed of its mætallic form while it is in a mineral state, as it is destitute of the true quantity of phlogiston, and, though it were not, would lose it by the action of the fire, it would come to pass that if its ore were melted without the addition of any inflammable matter, the cupreous earth or calx would be scorified and confounded with the unmetallic matters; and as all metallic matters, except gold and silver, are subject to this inconvenience as well as copper, the addition of an inflammable substance, in fluxing all ores that contain them, is a general rule that ought constantly to be observed.

Of Iron Ores.

Iron is seldom found pure and malleable in the earth; yet it is much seldomer found in the mineral state, properly so called, than any of the other metals: for most iron ores are scarce any thing more than a ferruginous earth mixed in different proportions with unmetallic earths and stones. Some of them, however, contain also volatile minerals, such as sulphur and arsenic; and therefore it is necessary to roast the iron ores, like all others, before you attempt to extract the metal out of them. That being done, they are to be smelted with a flux consisting of fusible and inflammable matters, as the general rule directs.

Iron is the commonest of all metals: nay, it is so universally diffused through the earth, that it is difficult to find any stone, earth, or sand, that does not contain some of it; and therefore none of these are usually considered and treated as iron ores, except such as contain a great deal of that metal, and melt easily. The hematites, emery, yellow pyrites, calamine, all contain a pretty considerable quantity

of iron ; but no body attempts to extract it from them, because they are very hard to melt.

Ferruginous earth being naturally of an orange colour, a stone or earth may be judged to contain iron, if either naturally, or after roasting, it appears to have one shade of yellow or red.

The singular property which iron has of being attracted by the magnet, and of being the only body, exclusive of all others, that is so, likewise affords us an easy method of discovering the presence of this metal among other matters, where it often exists in such a small quantity that it could not otherwise be found out. For this purpose the body in which iron is suspected to lurk, must be pulverised and torrefied with some inflammable matter ; and then the powder thus roasted being touched with a magnet, or an animated bar, if it contains any particles of iron they will infallibly adhere to the magnet or bar.

Of Tin Ores.

Tin is never found in the earth pure and malleable, but always in a mineral state, and always mineralized by arsenic. Tin ores are not sulphureous ; whence it comes, that though tin be the lightest of all metals, its ores are nevertheless heavier than those of other metals, as arsenic greatly exceeds sulphur in gravity. Some tin ores contain also a little iron. The ores of tin are to be washed, roasted, and smelted with a reducing flux, according to the general rules.

Of Lead Ores.

Lead, like tin, is never found but in a mineral state. It is most commonly mineralized by sulphur ; yet there are some lead ores which also contain arsenic.

Lead

Lead ores, as well as others, must be roasted and smelted with a reducing flux: however, as it is difficult to free them from all their sulphur by torrefaction only, the reducing flux employed in their fusion may be made up with a quantity of iron filings, which being incapable of any union with lead, and having a much greater affinity than that metal with sulphur, will on this occasion be of great service by interposing between them.

Of Quicksilver Ores.

Running mercury is sometimes found in certain earths, or grey, friable stones; but most commonly in a mineral state. It is always mineralized by sulphur, and by sulphur alone: so that cinabar is the only ore of quicksilver that we know of: and a very rich one it is, seeing it contains six or seven times as much mercury as sulphur.

Roasting can be of no use towards decomposing the ore of mercury, and separating its sulphur; because mercury being itself very volatile would be carried off by the fire together with the sulphur. In order therefore to part the two substances of which cinabar consists, recourse must necessarily be had to some third body, which will unite with one of them, and by that means separate it from the other. Now all the metals, except gold, having a greater affinity than mercury with sulphur, such a body is easily found: any metal but gold may be employed with success in this decomposition; but as iron hath a greater affinity with sulphur than any of the rest, and is moreover the only one that cannot unite with mercury, it must on account of these two qualities be preferred to all the rest.

Fixed alkalis are also well qualified to absorb the sulphur of cinabar. Cinabar must be decomposed in close vessels, and by the way of distillation; otherwise the mercury, as soon as it separates from the

the sulphur, will be dissipated in vapours and entirely lost.

In this operation it is needless to add either flux or phlogiston; because the cinabar is decomposed without melting, and the mercury, though in a mineral state, contains, like gold and silver, all the phlogiston requisite to secure its metalline properties.

Of the Ores of Regulus of Antimony.

Regulus of antimony is always found in a mineral state: it is mineralized by sulphur; but sometimes, though rarely, it is also combined with a little arsenic.

When the ore of regulus of antimony is to be decomposed, the first thing to be done is to expose it to a degree of heat too weak to melt its earthy and stony parts, but strong enough to fuse its reguline, together with its sulphureous parts, which by this means are separated from the earth, and united into one mass, known by the name of *Antimony*.

It is plain that this first operation, which is founded on the great fusibility of antimony, produces, with regard to the ore of regulus of antimony, the same effect that washing hath on other ores: so that after this first fusion nothing more is requisite to the obtaining of a pure regulus of antimony, but to separate it from its sulphur by roasting, and to melt it with some matter abounding in phlogiston, in the same manner as other metallic matters are treated. The term *Calcination* is generally used to express this torrefaction of antimony, by means whereof the metallic earth of the regulus of antimony is separated from its sulphur.

As regulus of antimony hath, like mercury, much less affinity with sulphur than the other metals have, it follows that antimony may be decomposed

posed by the same means as cinabar; but the regulus so obtained is adulterated with a portion of the additament made use of, which combines therewith.

There is still another process employed for obtaining the regulus of antimony: it consists, as was mentioned in its place, in detonating the mineral with a mixture of nitre and tartar, applied in such a proportion, that, after the detonation has consumed the sulphur, there may remain so much inflammable matter as will be sufficient to furnish the metalline earth of the antimony with the phlogiston necessary to preserve its metallic properties. But by this method less regulus is produced, than by calcining, or torrefying, and reducing, as usual.

Of the Ores of Bismuth.

The ore of bismuth consists of the semi-metal mineralized by arsenic, and of an unmetallic earth. It is very easy to decompose this ore, and to extract the bismuth it contains: for this purpose it need only be exposed to a moderate heat, whereby the arsenic will be dissipated in vapours, and the bismuth melted, which will then separate from the unmetallic earth. This earth, at least, in several ores of bismuth, possesses the property of tinging all vitrifiable matters, with which it is melted, of a beautiful blue colour.

To decompose the ore of bismuth no flux or inflammable matter is used; because this semi-metal is possessed, even in its mineral state, of all the phlogiston requisite to maintain its metalline properties; and its great fusibility makes it unnecessary to melt the unmetallic earth contained in its ore.

Of the Ores of Zinc.

Zinc is not generally obtained from a particular ore of its own; but sublimes during the fusion of a mineral, or rather a confused mass of minerals, that contains this semi-metal together with iron, copper, lead, sulphur, arsenic, and, like all other ores, an unmetallic earth.

Nevertheless there is a substance which may be considered as the proper ore of zinc, because it contains a pretty large quantity of that semi-metal, a little iron, and an unmetallic earth. It is called *calamine*, or *lapis calaminaris*: but hitherto the art of procuring zinc directly from this mineral hath no where been practised. Calamine is commonly employed only to convert copper into brass, or a yellow metal, by cementing it therewith. Indeed till lately no easy or practicable method of obtaining pure zinc from calamine was publicly known; for that semi-metal being volatile and very inflammable, its ore cannot be fused like others. Mr. Margraaf was the first, who, by mixing powdered charcoal with calamine in close vessels, obtained a perfect zinc from it, by the means of distillation or sublimation, as shall be shewn in our Practical chymistry.

Of Arsenical Minerals.

Arsenic, as well as sulphur, is naturally combined with almost all ores, or minerals, containing metallic substances. As it is very volatile, while the matters with which it is united are fixed, at least in comparison therewith, it is easily separated by sublimation.

The minerals that contain most arsenic are the white pyrites, orpiment, and cobalt. We have already considered the white pyrites: as to orpiment,

it consists of sulphur and arsenic. Both these substances being very volatile, it is difficult to separate them by sublimation: yet, with proper management, and a due regulation of the fire, this separation may be effected; because sulphur sublimes a little more easily than arsenic. But it is more convenient, as well as more expeditious, to make use of some additament that hath a greater affinity with one of those substances than with the other. Fixed alkalis and mercury, both of which have more affinity with sulphur than with arsenic, may be very properly employed on this occasion.

Cobalt is a mineral composed of arsenic, an unmetallic earth, and frequently bismuth: and as none of these are very volatile, except the arsenic, this may be easily separated from the rest by sublimation. The unmetallic earth which remains, has, like that of the ore of bismuth, the property of giving a blue colour to any vitrifiable matters melted with it: whence it is conjectured that cobalt and the ore of bismuth have a great resemblance, or are often blended with each other. Nevertheless Mr. Brant, an ingenious Swedish chymist, insists that they are very different: he pretends that the metallic substance contained in the true cobalt is a semi-metal of a peculiar nature, which hath been erroneously confounded with bismuth: and indeed he proves by a great number of curious experiments, related in the memoirs of the academy of Upsal, that these two metallic substances have properties that are essentially different: to that which is obtained from cobalt, he gives the name of *Regulus of cobalt*.

Besides the minerals already recited, there is found in the bowels of the earth another species of compound body, of which we have already taken notice; but which is supposed, with some degree of probability, to belong as much to the vegetable as to the mineral kingdom: I mean the *bitumens*; which

which the best observations oblige us to consider as vegetable oils, that by long lying in the earth have contracted an union with the mineral acids, and by that means acquired the thickness, consistence, and other properties observable in them.

By distillation they yield an oil, and an acid not unlike a mineral acid. Mr. Bourdelin has even demonstrated, by a very artful and ingenious process, that amber contains a manifest acid of sea-salt. See the Memoirs of the Royal Academy of Sciences.



CHAP. XVII.

Explanation of the Table of Affinities.

IT hath been shewn in the course of this work that the causes of almost all the phenomena, which chymistry exhibits, are deducible from the mutual affinities of different substances, especially the simplest. We have already explained, (chap. II.) what is meant by affinities, and have laid down the principal laws to which the relations of different bodies are subject. The late Mr. Geoffroy, one of the best chymists we have had, being convinced of the advantages which all who cultivate chymistry would receive from having constantly before their eyes a state of the best ascertained relations between the chief agents in chymistry, was the first who undertook to reduce them into order, and unite them all in one point of view, by means of a table. We are of opinion, with that great man, that this table will be of considerable use to such as are beginning to study chymistry, in helping them to

form a just idea of the relations which different substances have with one another; and that the practical chymist will thereby be enabled to account for what passes in several of his operations, otherwise difficult to be understood, as well as to judge what may be expected to result from mixtures of different compounds. These reasons have induced us to insert it at the end of this elementary treatise, and to give a short explanation of it here; especially as it will serve, at the same time, for a recapitulation of the whole work, in which the several axioms of this table are dispersed.

You have it here just as it was drawn up by Mr. Geoffroy, without any addition or alteration. I own, however, that it might be improved both ways: for since the death of that great chymist many experiments have been made, some of which have discovered new affinities, and others have raised exceptions to some of those laid down by him. But several reasons dissuade me from publishing a new table of affinities, containing all the emendations and innovations that might be made in the old one.

The first is, that many of the affinities lately discovered are not yet sufficiently verified, but, on the contrary, subject to be contested: In short, they are perhaps liable to more considerable objections and exceptions than the other.

The second is, that as Mr. Geoffroy's table contains all the fundamental affinities, it is more suitable to an elementary treatise than a much fuller one would be; seeing this would necessarily suppose the knowledge of many things not treated of by us, and of which it was not proper to say any thing in such a book as this.

However, as it is essential to our purpose that we lead none into error, we shall take care in explaining the affinities delivered by Mr. Geoffroy, to mention the principal objections and exceptions to which

which they are liable ; we shall moreover add a very few new ones, confining ourselves to such only as are elementary and well ascertained.

The upper line of Mr. Geoffroy's table, comprehends several substances used in chymistry. Under each of those substances are ranged in distinct columns several matters compared with them, in the order of their relation to that first substance ; so as that which is the nearest to it is that which hath the greatest affinity with it, or that which none of the substances standing below it can separate therefrom ; but which, on the contrary, separates them all when they are combined with it, and expels them in order to join itself therewith. The same is to be understood of that which occupies the second place of affinity ; that is, it has the same property with regard to all below it, yielding only to that which is above it : and so of all the rest.

At the top of the first column stands the character which denotes an acid in general. Immediately under this stands the mark of a fixed alkali, being placed there as the substance which has the greatest affinity with an acid. After the fixed alkali appears, the volatile alkali, whose affinity with acids yields only to the fixed alkali. Next come the absorbent earths ; and last of all metallic substances. Hence it follows that when a fixed alkali is united with an acid, it cannot be separated therefrom by any other substance ; that a volatile alkali united with an acid cannot be separated from it by any thing but a fixed alkali ; that an absorbent earth combined with an acid may be separated from it either by a fixed or by a volatile alkali ; and lastly, that any metallic substance combined with an acid may be separated from it by a fixed alkali, a volatile alkali, or an absorbent earth.

There are many important remarks to be made on this first column. First, it is making the rule too general to say that any acid whatever has a greater affinity with a fixed alkali, than with any

other substance. And indeed Mr Geoffroy himself hath made an exception with respect to the vitriolic acid: for in the fourth column, at the head of which stands that acid, we find the sign of the phlogiston placed above that of the fixed alkali, as having a greater affinity than the fixed alkali with the vitriolic acid. This is founded on the famous experiment, wherein vitriolated tartar and Glauber's salt are decomposed by means of the phlogiston, which separates the fixed alkalis of these neutral salts, and uniting with the vitriolic acid contained in them forms therewith a sulphur.

Secondly, nitre deflagrates, and is decomposed, by the contact of any inflammable matter whatever that is actually ignited; and the operation which produces phosphorus is no other than a decomposition of sea-salt, whose acid quits its alkaline basis to join with the phlogiston: now these facts furnish very strong reasons for believing that both these acids, as well as the vitriolic, have a stronger affinity with the phlogiston than with a fixed alkali. Lastly, as several experiments shew the vegetable acids to be only the mineral acids disguised and mortified, there are sufficient grounds for suspecting that acids in general have a greater affinity with the phlogiston than with fixed alkalis: so that instead of making an exception with regard to the vitriolic acid, it would perhaps be better to lay down this greater affinity as common to all acids whatever, and to place the phlogiston in the first column, immediately under the character which denotes an acid in general. This theory, however, stands in need of confirmation from other experiments*.

* Mr. Margraaph, an able German chymist, has made several experiments, which induce him to think that the acid of phosphorus is of a particular kind, and different from that of sea-salt. May it not be the marine acid, but altered by the union it has contracted with the phlogiston? Or may it not be, with respect to phosphorus, what the volatile sulphureous spirit is, with respect to sulphur? See the Memoirs of the royal academy of sciences of Berlin.

Thirdly,

Thirdly, in this same column the character of a volatile alkali is set above that of an absorbent earth, as having a greater affinity with acids; and yet these absorbent earths decompose the ammoniacal salts, drive away the volatile alkali from the acids, and assume its place. This is one of the first objections made against Mr. Geoffroy's table. His answer thereto is printed in the Memoirs of the academy of sciences for 1718, where his table also is to be found. We have already declared our opinion about this matter in treating of a volatile alkali.

Fourthly, in 1744, Mr. Geoffroy, brother to the author of the table, who hath done no less honour to chymistry than that eminent physician, gave in a memoir containing an exception to the last affinity in the first column, namely, that which places absorbent earths above metallic substances. He therein shews that alum may be converted into copperas by boiling it in iron vessels; that on this occasion the iron precipitates the earth of the alum, separates it from its acid, and assumes its place; so that of course it must have a greater affinity, than the absorbent earth of alum, with the vitrolic acid.

At the head of the second column stands the character of the marine acid, which signifies that the affinities of this acid are the subject of the column. Immediately below it is placed the mark of tin. As this is a metalline substance, and as the first column places metalline substances in the lowest degree of affinity with all acids, it is plain we must suppose fixed alkalis, volatile alkalis, and absorbent earths, to be placed here in order after the marine acid, and before tin. Tin, then, is of all metalline substances that which has the greatest affinity with the marine acid; and then follow regulus of antimony, copper, silver, mercury. Gold comes last of all; and there are no less than two vacant

vacant places above it. By this means it is in some sort excluded from the rank of substances that have an affinity with the marine acid. The reason thereof is that this acid alone is not capable of dissolving gold and combining therewith, necessarily requiring for that purpose the aid of the nitrous acid, or at least of the phlogiston.

The third column exhibits the affinities of the nitrous acid, the character whereof stands at its head. Immediately below it is the sign of iron, as the metal which has the greatest affinity with this acid; and then follow other metals, each according to the degree of its relation; to wit, copper, lead, mercury, and silver. In this column, as in the preceding one, we must suppose the substances, which in the first column stand above metallic substances, to be placed in their proper order before iron.

The fourth column is intended to represent the affinities of the vitriolic acid. Here Mr. Geoffroy has placed the phlogiston as the substance which has the greatest affinity with this acid, for the reason given in our explanation of the first column. Below it he has ranked fixed alkalis, volatile alkalis, and absorbent earths, to shew that this is an exception to the first column. As to metalline substances, he has set down but three, being those with which the vitriolic acid has the most perceptible affinity: these metals, placed in the order of their affinities, are iron, copper, and silver.

The fifth column shews the affinities of absorbent earths. As these earths have no sensible affinity but with acids, this column contains only the characters of the acids ranked according to the degree of their strength, or affinity with the earths; to wit, the vitriolic, the nitrous, and the marine acids. Underneath this last might be placed the acid of vinegar, or the vegetable acid.

The

The sixth column expresses the affinities of fixed alkalis with acid, which are the same with those of absorbent earths. Moreover, we find sulphur placed here below all the acids; because liver of sulphur, which is a combination of sulphur with a fixed alkali, is actually decomposed by any acid: for any acid precipitates the sulphur and unites with the alkali.

Immediately over the sulphur, or in the same square with it, might be set a mark denoting the volatile sulphureous spirit; because, like sulphur, it has less affinity than any other acid with fixed alkalis. Oils might also be ranked with sulphur, because they unite with fixed alkalis, and therewith form soaps, which are decomposed by any acid whatever.

The seventh column points out the affinities of volatile alkalis, which are likewise the same as those of absorbent earths; and the vegetable acid might be placed here also under the marine acid.

The eighth column specifies the affinities of metallic substances with acids. The affinities of the acids, which with respect to fixed alkalis, volatile alkalis, and absorbent earths, succeeded each other uniformly, do not appear in the same order here. The marine acid, instead of being placed below the vitriolic and nitrous acids, stands, on the contrary, at their head; because, in fact, this acid separates metalline substances from all the other acids with which they happen to be united, and, forcing these acids to quit possession, intrudes into their place. Nevertheless, this is not a general rule; for several metalline substances must be excepted, particularly iron and copper.

The ninth column declares the affinities of sulphur. Fixed alkalis, iron, copper, lead, silver, regulus of antimony, mercury, and gold, stand below in the order of their affinities. With regard to gold it must be observed, that it will not unite with

with pure sulphur; it suffers itself to be dissolved only by the liver of sulphur, which is known to be a composition of sulphur and fixed alkali,

At the head of the tenth column appears mercury, and beneath it several metalline substances, in the order of their affinities with it. Those metalline substances are gold, silver, lead, copper, zinc, and regulus of antimony.

It is proper to remark on this column that regulus of antimony, which stands the lowest, unites but very imperfectly with mercury; and that after a seeming union of these two metallic substances hath been obtained, by a tedious triture with the addition of water, they do not continue long united, but spontaneously separate from each other in a short time. Iron and tin are here excluded; the former with great reason, because hitherto it hath not been clearly proved, by any known experiment, that ever mercury was united with iron: but the same objection cannot be made to tin, which amalgamates very well with mercury, and might therefore be placed in this column nearly between lead and copper. I use the word *nearly*, because the different degrees of affinity between metalline substances and mercury are not so exactly determined, as the other relations before considered; seeing they generally unite with it, without excluding one another. We can therefore scarce judge of the degree of affinity that belongs to each, but by the greater or less readiness of each to amalgamate therewith.

The eleventh column shews that lead has a greater affinity with silver than with copper.

The twelfth, that copper has a greater affinity with mercury than with calamine.

The thirteenth, that silver has a greater affinity with lead than with copper.

The fourteenth contains the affinities of iron. Regulus of antimony stands immediately underneath

neath it, as being the metallic substance which has the greatest affinity with it. Silver, copper, and lead are placed together in the next square below, because the degrees of affinity which those metals have with iron are not exactly determined.

The same is to be said of the fifteenth column: regulus of antimony stands at its head; iron is immediately below it; and below the iron the same three metals occupy one square as before.

Lastly, the sixteenth column indicates that water has a greater affinity with spirit of wine than with salts. By this general expression must not be understood any saline substance whatever; but only the neutral salts, which spirit of wine frees from the water that kept them in solution. Fixed alkalis, on the contrary, as well as the mineral acids, have a greater affinity than spirit of wine with water: so that these saline substances, being well dephlegmated, and mixed with spirit of wine, imbibe the water it contains, and rectify it.

To these might be added another short column, having spirit of wine at its head: immediately below it should be the character of water, and below that the mark of oil. This column would shew that spirit of wine has a greater affinity with water than with oils; because any oily matter whatever, that is dissolved in spirit of wine, may be actually separated from it by the affusion of water. This rule admits of no exception but in one case; which is when the oily substance partakes of the nature of soap, by having contracted an union with some saline matter. But as this must be imputed wholly to that adventitious saline matter being superadded to the oily substance, it is no just foundation for an exception; and the affinity in question is nevertheless general.

We have now delivered every thing material that we had to say concerning Mr Geoffroy's table of affinities. It is, as we observed before, of exceeding

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ing great service, as it collects into one view the principal truths laid down in this Treatise. Indeed the most advantageous way of using it is, not to delay consulting it till you have read the book through, but to turn to it while you are reading, as oft as any affinity between bodies is treated of; which it will imprint more strongly on your mind, by representing it in a manner before your eyes.



CH A P. XVIII.

The THEORY of CONSTRUCTING the VESSELS most commonly used in CHYMISTRY.

CHYMISTS cannot perform the operations of their art without the help of a considerable number of vessels, instruments, and furnaces, adapted to contain the bodies on which they intend to work, and to apply to them the several degrees of heat required by different processes. It is therefore proper, before we advance to the operations themselves, to consider particularly and minutely what relates to the instruments with which they are to be performed.

Vessels intended for chymical operations should, to be perfect, be able to bear, without breaking, the sudden application of great heat and great cold; be impenetrable to every thing, and unalterable by any solvent; unvitriifiable, and capable of enduring the most violent fire without melting; but hitherto no vessels have been found with all these qualities united.

They are made of sundry materials; namely of metal, of glass, and of earth. Metalline vessels especially

especially those made of iron or copper, are apt to be corroded by almost every saline, oily, or even aqueous substance. For this reason, in order to render the use of them a little more extensive, they are tinned on the inside. But, notwithstanding this precaution, they are on many occasions not to be trusted; and should never be employed in any nice operations which require great accuracy: they are, moreover, incapable of resisting the force of fire.

Earthen vessels are of several sorts. Some, that are made of a refractory earth, are capable of being suddenly exposed to a strong fire without breaking, and even of sustaining a great degree of heat for a considerable time: but they generally suffer the vapours of the matters which they contain, as well as vitrified metals, to pass through them, especially the glass of lead, which easily penetrates them and runs through their pores as through a sieve. There are others made of an earth that, when well baked, looks as if it were half vitrified: These being much less porous, are capable of retaining the vapours of the matters which they contain, and even glass of lead in fusion; which is one of the severest trials a vessel can be put to: but then they are more brittle than the other sort.

Good glass vessels should constantly be employed in preference to all others, whenever they can possibly be used: and that not only because they are no way injured by the most active solvents, nor suffer any part of what they contain to pass through, but also because their transparency allows the chymist to observe what passes within them: which is always both curious and useful. But it is pity that vessels of this sort should not be able to endure a fierce fire without melting. We shall take care, when we come to describe the several sorts of chymical instruments, and the manner of using them,

VOL. I. P

to note what vessels are to be preferred to others on different occasions.

Distillation, as it hath been already said, is an operation by which we separate from a body, by the help of a gradual heat, the several principles of which it consists.

There are three methods of distilling. The first is performed by applying the heat over the body whose principles are to be extracted. In this case, as the liquors, when heated and converted into vapours, constantly endeavour to fly from the center of heat, they are forced to re-unite in the lower part of the vessel, that contains the matter in distillation, and so passing through the pores or holes of that vessel, they fall into another cold vessel applied underneath to receive them. This way of distilling is on this account called *Distilling per descensum*. It requires no other apparatus than two vessels figured like segments of hollow spheres, whereof that which is pierced with little holes, and intended to contain the matter to be distilled, should be much less than the other, which is to contain the fire, and to fill its aperture exactly; the whole together being supported vertically upon a third vessel, which is to serve the purpose of a recipient, admitting into its mouth the convex bottom of the vessel containing the matter to be distilled, which must accurately fill it. This method of distilling is but little used.

The second method of distilling is performed by applying the heat underneath the matter to be decomposed. On this occasion the liquors being heated, rarefied, and converted into vapours, rise, and are condensed in a vessel contrived for that purpose, which we shall presently describe. This way of distilling is called *Distilling per ascensum*, and is much used.

The vessel in which this distillation *per ascensum* is performed we call an *alembic*.

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There are several sorts thereof differing from one another both in the matter of which, and the manner in which, they are made.

Those employed to draw the odoriferous waters and essential oils of plants are generally made of copper, and consist of several pieces. The first, which is designed to contain the plant, is formed nearly like a hollow cone, the vertex whereof is drawn out in the shape of a hollow cylinder or tube: this part is named the *cucurbit*, and its tube the *neck* of the *alembic*. To the upper end of this tube another vessel is soldered: this is called the *head*, and commonly has likewise the form of a cone, joined to the neck of the alembic by its base, round which, on the inside, is hollowed a small groove, communicating with an orifice that opens at its most depending part. To this orifice is soldered a small pipe in a direction sloping downwards, which is called the *nose*, *spout*, or *beak*, of the alembic.

As soon as the matters contained in the alembic grow hot, vapours begin to arise from them, and ascending through the neck of the alembic into the head, are by the sides thereof stopped and condensed: from thence they trickle down in little streams to the groove, which conveys them to the spout; and by that they pass out of the alembic into a glass vessel with a long neck, the end of the spout being introduced into that neck, and luted thereto.

To facilitate the refrigeration and condensation of the vapours circulating in the head, all alembics of metal are moreover provided with another piece, which is a kind of large pan of the same metal, fitted and soldered round the head. This piece serves to keep cold water in, which incessantly cools the head, and therefore it is called the *refrigeratory*. The water in the refrigeratory itself grows hot after some time, and must therefore be changed

ed occasionally; the heated water being first drawn off by means of a cork fixed near the bottom of the refrigeratory. All copper alembics should be tinned on the inside for the reasons already given.

When saline spirits are to be distilled, alembics of metal must not be used; because the saline vapours would corrode them. In this case recourse must be had to alembics of glass. These consist of two pieces only; namely, a *cucurbit*, whose superior orifice is admitted into and exactly luted with its *head*, which is the second piece.

In general, as alembics require that the vapours of the matter to be distilled should rise to a considerable height, they ought to be used only when the most volatile principles are to be drawn from bodies: And the lighter and more volatile the substances to be separated by distillation are, the taller must the alembic be; because the most ponderous parts, being unable to rise above a certain height, fall back again into the cucurbit as soon as they arrive there, leaving the lighter to mount alone, whose volatility qualifies them to ascend into the head.

When a matter is to be distilled, that requires a very tall alembic, and yet does not admit of a metalline vessel, the end will be best answered by a glass vessel of a round or oval shape, having a very long neck, with a small head fitted to its extremity. Such a vessel serves many purposes: It is sometimes employed as a receiver, and at other times as a digesting vessel; on which last occasion it goes under the name of a *matrafi*. When one of these provided with a head is applied to the purpose of distilling, it forms a sort of alembic.

There are some alembics of glass, blown in such a manner by the workmen, that the body and head form but one continued piece. As these alembics

do not stand in need of having their several pieces luted together, they are very useful on some occasions, when such exceeding subtile vapours rise as are capable of transpiring through lutes. The head must have an apperture at the top, provided with a short tube, through which by means of a funnel with a long pipe, the matter to be distilled may be introduced into the cucurbit. This is to be exactly closed with a glass stopple, the surface whereof must be made to fit the inside of the tube in every point, by rubbing these two pieces well together with emery.

Another sort of alembic hath also been invented, which may be used with advantage when *cobobation* is required; that is, when the liquor obtained by distillation is to be returned upon the matter in the cucurbit; and especially when it is intended that this cobobation shall be repeated a great number of times. The vessel we are speaking of is constructed exactly in the same manner as that last described; except that its beak, instead of being in a straight line, as in the other alembics, forms a circular arch, and re-enters the cavity of the cucurbit, in order to convey back again the liquor collected in the head. This instrument hath commonly two beaks opposite to each other, both turned in this manner, and is called a *pelican*: It saves the artist the trouble of frequently unluting and reluting his vessels, as well as the loss of a great many vapours.

There are certain substances which in distillation afford matters in a concrete form, or rise wholly in the form of a very light powder, called *flowers*.

When such substances are to be distilled, the cucurbit which contains them is covered with a head without a nose, which is named a *blind-head*.

When the flowers rise in great quantities and very high, a number of heads is employed to collect them; or rather a number of a kind of pots, consisting

sisting of a body only without any bottom, which fitting one into the other form a canal, that may be lengthened or shortened at pleasure, according as the flowers to be sublimed are more or less volatile. The last of the heads, which terminates the canal, is quite close at one end, and makes a true blind-head. These vessels are called *aludels*: they are usually of earthen or stone ware.

All the vessels above mentioned are fit only for distilling such light volatile matters as can be easily raised and brought over; such as phlegm, essential oils, fragrant waters, acid oily spirits, volatile alkalis, &c. But when the point is to procure by distillation principles that are much less volatile, and incapable of rising high, such as the thick fetid oils, the vitriolic, the nitrous, and the marine acids, &c. we are under a necessity of having recourse to other vessels, and another manner of distilling.

It is easy to imagine that such a vessel must be much lower than the alembic. It is indeed no more than a hollow globe, whose upper part degenerates into a neck or tube, that is bent into a horizontal position; for which reason this instrument is called a *retort*: it is always of one single piece.

The matter to be distilled is introduced into the body of the retort by means of a laddle with a long tubular shank. Then it is set in a furnace built purposely for this use, and so that the neck of the retort coming out of the furnace may, like the nose of the alembic, stand in a sloping position, to facilitate the egress of the liquors, which by its means are conveyed to a receiver, into which it is introduced, and with which it is luted. This way of distilling, in which the vapours seem rather to be driven out of the vessel horizontally and laterally, than raised up and sublimed, is for that reason called distillation *per latus*.

Retorts

Retorts are, of all the instruments of distillation, those that must sustain the greatest heat, and resist the strongest solvents; and therefore they must not be made of metal. Some, however, which are made of iron may do well enough on certain occasions: the rest are either of glass or earth. Those of glass, for the reasons above given, are preferable to the other sort, in all cases where they are not to be exposed to such a force of fire as may melt them. The best glass, that which stands both heat and solvents best, is that in which there are fewest alkaline salts. Of this sort is the green German glass: the beautiful white crystal glass is far from being equally serviceable.

Retorts, as well as alembics, may be of different forms. For example, some matters are apt to swell, and rise over the neck of the retort in substance, without suffering any decomposition; when such matters are to be distilled in a retort, it is proper that the body of the vessel, instead of being globular, be drawn out into the form of a pear, so as nearly to resemble that of a cucurbit. In a retort of this kind, the distance between the bottom and the neck being much greater than in those whose bodies are spherical, the matters contained have much more room for expansion; so that the inconvenience here mentioned is thereby prevented. Retorts of this form are called English retorts. As they hold the middle place between alembics and common retorts, they may be used to distil such matters as have a mean degree of volatility between the greatest and the least.

It is moreover proper to have, in a laboratory, sundry retorts with necks of different diameters. Wide necks will be found the fittest for conveying thick matters, and such as readily become fixed; for instance, some very thick fetid oils, butter of antimony, &c.: for as these matters acquire a consistence as soon as they are out of the reach of a certain

tain degree of heat, they would soon choak a narrow neck, and by stopping the vapours which rise at the same time from the retort, might occasion the bursting of the vessels.

Some retorts are also made with an opening on their upper side, like that of tubulated glass alembics, which is to be closed in the same manner with a glass stopple. These retorts are also called tubulated retorts, and ought always to be used whenever it is necessary to introduce fresh matter into the retort during the operation; seeing it may be done by means of this invention, without unluting and reluting the vessels; which ought always to be avoided as much as possible.

One of the things that most perplexes the chymists, is the prodigious elasticity of many different vapours, which are frequently discharged with impetuosity during the distillation, and are even capable of bursting the vessels with explosion, and with danger to the artist. On such occasions it is absolutely necessary to give these vapours vent, as we shall direct in its proper place: but as that can never be done without losing a great many of them; as some of them in particular are so elastic that scarce any at all would remain in the vessel; for instance, those of the spirit of nitre, and especially those of the smoking spirit of salt; the practice is to make use of very large receivers, of about eighteen or twenty inches diameter, that the vapours may have sufficient room to circulate in, and by applying to the wide surface presented them by the extensive inside of such a large vessel, may be condensed into drops. These huge receivers are commonly in the form of hollow globes, and are called ballons.

To give these vapours still more room, ballons have been contrived with two open gullets in each, diametrically opposite to one another; whereof one admits the neck of the retort, and the other is received

received by one of the gullets of a second ballon of the same form, which is joined in like manner to a third, and so on. By this artifice the space may be enlarged at pleasure. These ballons with two necks are called adopters.

Operations on bodies that are absolutely fixed, as metals, stones, sand, &c. require only such vessels as are capable of containing those bodies, and resisting the force of fire. These vessels are little hollow pots of different dimensions, which are called crucibles. Crucibles can hardly be made of any thing but earth; they ought to have a cover of the same material fitted to shut them close. The best earth we know is that whereof those pots are made in which butter is brought from Bretagne: these pots themselves are exceeding good crucibles; and they are almost the only ones that are capable of holding glass of lead in fusion, without being penetrated by it.

For the roasting of ores, that is, freeing them by the help of fire, from their sulphureous and arsenical parts, little cups made of the same material with crucibles are used; but they are made flat, shallow, and wider above than below, that these volatile matters may the more freely exhale. These vessels are called tests or scorifiers: they are scarce ever used but in the docimastic art, that is, in making small assays of ores.

CHAP.



C H A P. XIX.

The THEORY of CONSTRUCTING the FURNACES most commonly used in Chymistry.

SKILL in conducting and applying fire properly, and determining its different degrees, is of very great consequence to the success of chymical operations.

As it is exceeding difficult to govern and moderate the action of fire, when the vessels in which any operation is performed are immediately exposed to it, chymists have contrived to convey heat to their vessels, in nice operations, through different mediums, which they place occasionally between those vessels and the fire.

Those intermediate substances in which they plunge their vessels are called baths. They are either fluid or solid: the fluid baths are water or its vapours. When the distilling vessel is set in water, the bath is called *balneum mariæ*, or the *water-bath*; and the greatest degree of heat of which it is susceptible is that of boiling water. When the vessel is exposed only to the vapours which exhale from water, this forms the *vapour-bath*; the heat of which is nearly the same with that of the *balneum mariæ*. These baths are useful for distilling essential oils, ardent spirits, sweet-scented waters; in a word, all such substances as cannot bear a greater heat, without prejudice either to their odour, or to some of their other qualities.

Baths may also be made of any other fluids, such as oils, mercury, &c. which are capable of receiving and communicating much more heat

but they are very seldom used. When a more considerable degree of heat is required, a bath is prepared of any solid matter reduced to a fine powder, such as sand, ashes, filings of iron, &c. The heat of these baths may be pushed so far as to make the bottom of the vessel become faintly red. By plunging a thermometer into the bath, by the side of the vessel, it is easy to observe the precise degree of heat applied to the substance on which you are working. It is necessary that the thermometers employed on this occasion be constructed on good principles, and so contrived as to be easily compared with those of the most celebrated natural philosophers. Those of the illustrious Reaumur are most used and best known, so that it would not be amiss to give them the preference. When a greater heat is required than any of those baths can give, the vessels must be set immediately on live coals, or in a flaming fire: this is called working with a naked fire; and in this case it is much more difficult than in the other to determine the degrees of heat.

There are several ways of applying a naked fire. When the heat or flame is reflected upon the upper part of a vessel which is exposed to the fire, this is called a reverberated heat. A melting heat is that which is strong enough to fuse most bodies. A forging heat is that of a fire which is forcibly excited by the constant blast of a pair of bellows, or more.

There is also another sort of fire which serves very commodiously for many operations, because it does not require to be fed or frequently mended: this is afforded by a lamp with one or more wicks, and may be called a lamp-heat. It is scarce ever employed but to heat baths, in operations which require a gentle and long-continued warmth: if it hath any fault, it is that of growing gradually hotter.

All the different ways of applying fire require fur-

furnaces of different constructions: we shall therefore describe such as are of principal and most necessary use.

Furnaces must be divided into different parts or stories, each of which has its particular use and name.

The lower part of the furnace designed for receiving the ashes, and giving passage to the air, is called the ash-hole. The ash-hole is terminated above by a grate, the use of which is to support the coals and wood, which are to be burnt thereon: this part is called the fire-place. The fire-place is in like manner terminated above by several iron bars, which lie quite a-cross it from right to left, in lines parallel to each other: the use of these bars is to sustain the vessels in which the operations are to be performed. The space above these bars to the top of the furnace is the upper story, and may be called the laboratory of the furnace. Lastly, some furnaces are quite covered above by means of a kind of vaulted roof called the dome.

Furnaces have moreover several apertures: one of these is at the ash-hole, which gives passage to the air, and through which the ashes that fall through the grate are raked out; this aperture is called the ash-hole door: another is at the fire-place, through which the fire is supplied with fuel, as occasion requires; this is called the mouth or door of the fire-place, or the stoke-hole: there is a third in the upper story, through which the neck of the vessel passes; and a fourth in the dome for carrying off the fuliginosities of combustible matters, which is called the chimney.

To conclude, there are several other openings in the several parts of the furnace, the use whereof is to admit the air into those places, and also, as they can be easily shut, to incite or slacken the activity of the fire, and so to regulate it; which has procured them the title of registers. All the other openings

openings of the furnace should be made to shut very close, the better to assist in governing the fire; by which means they likewise do the office of registers.

In order to our forming a just and general idea of the construction of furnaces, and of the disposition of the several apertures in them, with a view to increase or diminish the activity of the fire, it will be proper to lay down, as our ground-work, certain principles of natural philosophy, the truth of which is demonstrated by experience.

And first, every body knows that combustible matters will not burn or consume unless they have a free communication with the air; inasmuch that if they be deprived thereof, even when burning most rapidly, they will be extinguished at once: that consequently combustion is greatly promoted by the frequent accession of fresh air, and that a stream of air, directed so as to pass with impetuosity through burning fuel, excites the fire to the greatest possible activity.

Secondly, it is certain that the air which touches, or comes near ignited bodies is heated, rarefied, and rendered lighter than the air about it, that is, further distant from the centre of heat; and consequently that this air, so heated and become lighter, is necessarily determined thereby to ascend and mount aloft, in order to make room for that which is less heated and not so light, which by its weight and elasticity tends to occupy the place quitted by the other. Another consequence hereof is, that if fire be kindled in a place enclosed every where but above and below, a current of air will be formed in that place, running in a direction from the bottom to the top; so that if any light bodies be applied to the opening below, they will be carried up towards the fire; but, on the contrary, if they be held at the opening above,

they will be impelled by a force which will drive them up and carry them away from the fire.

Thirdly and lastly, it is a truth demonstrated in hydraulics that the velocity of a given quantity of of any fluid, determined to flow in any direction whatever, is so much the greater the narrower the channel is to which that fluid is confined; and consequently that the velocity of a fluid will be increased by making it run from a wider through a narrower passage.

These principles being established, it is easy to apply them to the construction of furnaces. First, if a fire be kindled in the fire-place of a furnace, which is open on all sides, it burns nearly as if it were in the open air. It has with the surrounding air a free communication; so that fresh air is continually admitted to facilitate the entire combustion of the inflammable matters employed as fuel. But there being nothing to determine that air to pass with rapidity through the fire in this case, it does not at all augment the activity thereof, but suffers it to waste away quietly.

Secondly, if the ash-hole or dome of a furnace, in which a fire is burning, be shut quite close, then there is no longer any free communication between the air and the fire: if the ash-hole be shut, the air is debarred from having free access to the fire; if the dome be stopt, the egress of the air rarefied by the fire is prevented; and consequently the fire must in either case burn very faintly and slowly, gradually die away, and at last go quite out.

Thirdly, if all the openings of the furnace be wholly closed, it is evident that the fire will be very quickly extinguished.

Fourthly, if only the lateral openings of the fire-place be shut, leaving the ash-hole and upper part of the furnace open; it is plain that the air entering by the ash-hole will necessarily be determined to go out at top, and that consequently a current

of air will be formed, which will pass through the fire, and make it burn briskly and vigorously.

Fifthly, if both the ash-hole and the upper story of the furnace be of some length, and form canals either cylindric or prismatic, then the air being kept in the same direction through a longer space, the course of its stream will be both stronger and better determined, and consequently the fire will be more animated by it.

Sixthly and lastly, if the ash-hole and the upper part of the furnace, instead of being cylindric or prismatic canals, have the form of truncated cones or pyramids, standing on their bases, and so ordered that the upper opening of the ash-hole, adjoining to the fire-place, may be wider than the base of the superior cone or pyramid, then the stream of air, being forced to pass incessantly from a larger channel through a smaller, must be considerably accelerated, and procure to the fire the greatest activity which it can receive from the make of a furnace.

The materials fittest for building furnaces are, 1. Bricks, joined together with potters clay mixed with sand and moistened with water. 2. Potters clay mingled with potsherds, moistened with water, and baked in a violent fire. 3. Iron; of which all furnaces may be made, with this precaution, that the inside may be provided with a great many prominent points, as fastenings for a coat of earth, with which the internal parts of the furnace must necessarily be covered to defend it from the action of the fire.

The reverberating furnace is one of those that are most employed in chymistry: it is proper for distillations by the retort, and should be constructed in the following manner.

First, the use of the ash-hole being, as was said, to give passage to the air and to receive the ashes, no bad consequence can attend its being made pretty high:

high: it may have from twelve to twenty or twenty-four inches in height. Its aperture should be wide enough to admit billets of wood, when a great fire is to be made.

Secondly, the ash-hole must be terminated at its upper part by an iron grate, the bars of which should be very substantial, that they may resist the action of the fire: this grate is the bottom of the first-place, and destined to support the coals. In the lateral part of the fire-place, and nearly about the same height with the grate, there should be a hole of such a size that it may easily admit charcoal, as well as little tongs and shovels for managing the fire. This aperture or mouth of the fire-place should be perpendicularly over the mouth of the ash-hole.

Thirdly, from six to eight or ten inches high above the grate over the ash-hole, little apertures must be made in the walls of the furnace, of eight or ten lines in diameter, an inch from one another, and those in one side must be diametrically opposite to those in the other. The use of these holes is to receive bars of iron for the retort to rest on; which should be, as I said, at different heights, in order to accommodate retorts of different sizes. At the upper extremity of this part of the furnace, which reaches from the iron bars to the top, the height whereof should be somewhat less than the width of the furnace, must be cut a semi-circular aperture for the neck of the retort to come through. This hole must by no means be over the doors of the fire-place and ash-hole; for then, as it gives passage to the neck of the retort, it must of course be opposite to the receiver, and in that case the receiver itself would stand over against those two apertures; which would be attended with this double inconvenience, that the receiver would not only grow very hot, but greatly embarrass the operator, whose free access to the fire-place and ash hole would be thereby

thereby obstructed. It is proper, therefore, that the semi-circular cut we are speaking of be so placed that when the greatest ballons are luted to the retort they may leave an open passage to the fire-place and ash-hole.

Fourthly, in order to cover in the laboratory of the reverberating furnace, there must be a roof made for it in the form of a cupola, or concave hemisphere, having the same diameter as the furnace. This dome should have a semicircular cut in its rim answering to that above directed to be made in the upper extremity of the furnace, so that, when adjusted to each other, the two together may form a circular hole for the neck of the retort to pass through. At the top of this dome there must also be a circular hole of three or four inches diameter, carrying a short tapering funnel of the same diameter, and three inches high, which will serve for a chimney to carry off all fuliginosities, and accelerate the current of the air. This passage may be shut at pleasure with a flat cover. Moreover, as it is necessary that the dome should be taken off and put on with ease, it should have two ears or handles for that purpose: a portative or moveable furnace should also have a pair of handles, fixed opposite to each other, between the ash-pole and the fire-place.

Sixthly and lastly, a conical canal must be provided of about three foot long, and sufficiently wide at its lower end to admit the funnel of the aperture at the top of the dome. This conical tube is to be applied to the dome when the fire is required to be extremely active: it tapers gradually from its base upwards, and breaks off as if truncated at top, where it should be about two inches wide.

Besides the apertures already mentioned as necessary to a reverberating furnace, there must also be many other smaller holes made in its ash-hole, fire-place, laboratory, and dome, which must all be so contrived

contrived as to be easily opened and shut with stopples of earth : these holes are the registers of the furnace, and serve to regulate the activity of the fire, according to the principles before laid down.

When the action of the fire is required to be exactly uniform and very brisk, it is necessary to stop carefully with moist earth all the little chinks in the juncture of the dome with the furnace, between the neck of the retort and the circular hole through which it passes, and which it never fills exactly, and lastly, the holes which receive the iron bars that sustain the retort.

It is proper to have, in a laboratory, several reverberating furnaces of different magnitudes ; because they must be proportioned to the size of the retorts employed. The retort ought to fill the furnace, so as to leave only the distance of an inch between it and the inside of the furnace.

Yet when the retort is to be exposed to a most violent fire, and especially when it is required that the heat shall act with equal force on all parts of the furnace, and as strongly on its vault as on its bottom, a greater distance must be left between the retort and the inside of the furnace ; for then the furnace may be filled with coals, even to the upper part of the dome. If moreover some pieces of wood be put into the ash-hole, the conical canal fitted on to the funnel of the dome, and all the apertures of the furnace exactly closed, except the ash-hole and the chimney, the greatest heat will then be excited that this furnace can produce.

The furnace now described may also be employed in many other chymical operations. If the dome be laid aside, an alembic may very well be placed therein : but then the space, which will be left between the body of the alembic and the top of the upper part of the furnace, must be carefully filled up with Windsor-loam moistened ; for without that precaution the heat would soon reach the
very

very head, which ought to be kept as cool as possible, in order to promote the condensation of the vapours. On this occasion therefore it will be proper to leave no holes open in the fire-place, but the lateral ones; of which also those over-against the receiver must be stopped.

A pot, or broad-brimmed earthen pan, may be placed over this furnace, and being so fitted to it as to close the upper part thereof accurately, and filled with sand, may serve for a sand-heat to distil with.

The bars designed to support distilling vessels being taken out, a crucible may stand therein, and many operations be performed that do not require the utmost violence of fire. In a word, this furnace is one of the most commodious that can be, and more extensively useful than any other.

The melting furnace is designed for applying the greatest force of heat to the most fixed bodies, such as metals and earths. It is never employed in distilling; it is of no use but for calcination and fusion: and consequently need not admit any vessels but crucibles.

The ash-hole of this furnace differs from that of the reverberating furnace only in this, that it must be higher, in order to raise the fire-place to a level with the artist's hand; because in that all the operations of this furnace are performed. The ash-hole therefore must be about three foot high: and this height procures it moreover the advantage of a good draught of air. For the same reason, and in consequence of the principles we laid down, it should be so built that its width lessening insensibly from the bottom to the top, it may be narrower where it opens into the fire-place than any where below.

The ash-hole is terminated at its upper end, like that of the reverberating furnace, by a grate, which serves for the bottom of the fire-place, and ought to

to be very substantial that it may resist the violence of the fire. The inside of this furnace is commonly an elliptic curve; because it is demonstrated by mathematicians that surfaces having that curvature reflect the rays of the sun, or of fire, in such a manner that meeting in a point, or a line, they produce there a violent heat. But, to answer this purpose, those surfaces must be finely polished; an advantage hardly procurable to the internal surface of this furnace, which can be made of nothing but earth: besides, if it were possible to give it a polish, the violent action of the fire that must be employed in this furnace would presently destroy it. Yet the elliptical figure must not be entirely disregarded: for, if care be taken to keep the internal surface of the furnace as smooth as possible, it will certainly reflect the heat pretty strongly, and collect it about the center.

The fire-place of this furnace ought to have but four apertures.

First, that of the lower grate, which communicate with the ash-hole.

Secondly, a door in its fore-side, through which may be introduced coals, crucibles, and tongs for managing them: this aperture should be made to shut exactly with a plate of iron, having its inside coated with earth, and turning on two hinges fixed to the furnace.

Thirdly, over this door a hole slanting downwards, towards the place where the crucible is to stand. The use of this hole is to give the operator an opportunity of examining the condition of the matters contained in his crucible without opening the door of the fire-place: this hole should be made to open and shut easily, by means of a stopple of earth.

Fourthly, a circular aperture of about three inches wide in the upper part or vault of the furnace, which should gradually lessen and terminate,

nate, like that of the dome of the reverberating furnace, in a short conical funnel of about three inches long, and fitted to enter the conical pipe before described, which is applied when the activity of the fire is to be increased.

When this furnace is to be used, and a crucible to be placed in it, care must be taken to set on the grate a cake of baked earth, somewhat broader than the foot of the crucible. The use of this stand is to support the crucible, and raise it above the grate, for which purpose it should be two inches thick. Were it not for this precaution the bottom of the crucible, which would stand immediately on the grate, could never be thoroughly heated, because it would be always exposed to the stream of cold air, which enters by the ash-hole. Care should also be taken to heat this earthen bottom red-hot before it be placed in the furnace, in order to free it from any humidity, which might otherwise happen to be driven against the crucible during the operation, and occasion its breaking.

We omitted to take notice in speaking of the ash-hole, that, besides its door, it should have about the middle of its height a small hole, capable of receiving the nosel of a good perpetual bellows, which is to be introduced into it and worked, after the door is exactly shut, when it is thought proper to excite the activity of the fire to the utmost violence.

The forge is only a mass of bricks of about three foot high, along whose upper surface is directed the nose or pipe of a pair of large perpetual bellows, so placed that the operator may easily blow the fire with one hand. The coals are laid on the hearth of the forge near the nose of the bellows; they are confined if necessary, to prevent their being carried away by the wind of the bellows, within a space inclosed by bricks; and then, by pulling the bellows, the fire is continually kept up in

in its greatest activity. The forge is of use when there is occasion to apply a great degree of heat suddenly to any substance, or when it is necessary that the operator be at liberty to handle frequently the matters which he proposes to fuse or calcine.

The cupelling furnace is that in which gold and silver are purified, by the means of lead, from all alloy of other metallic substances. This furnace must give a heat strong enough to vitrify lead, and therewith all the alloy which the perfect metals may contain. This furnace is to be built in the following manner.

First, of thick iron-plates, or of some such composition of earth as we recommended for the construction of furnaces, must be formed a hollow quadrangular prism, whose sides may be about a foot broad, and from ten to eleven inches high; and extending from thence upwards may converge towards the top, so as to form a pyramid truncated at the height of seven or eight inches, and terminated by an aperture of the width of seven or eight inches every way. The lower part of the prism is terminated, and closed, by a plate of the same materials of which the furnace is constructed.

Secondly, in the foreside or front of this prism there is an opening of three or four inches in height by five or six inches in breadth: This opening, which should be very near the bottom, is the door of the ash-hole. Immediately over this opening is placed an iron grate, the bars of which are quadrangular prisms of half an inch square, laid parallel to each other, and about eight or nine inches asunder, and so disposed that two of their angles are laterally opposite, the two others looking one directly upwards and the other downwards. As in this situation the bars of the grate present to the fire-place very oblique surfaces, the
ashes

ashes and very small coals do not accumulate between them, or hinder the free entrance of the air from the ash-hole. This grate terminates the ash-hole at its upper part, and serves for the bottom of the fire-place.

Thirdly, three inches, or three and a half, above the grate, there is in the fore-side of the furnace another opening terminated by an arch for its upper part, which consequently has the figure of a semicircle: It ought to be four inches wide at bottom, and three inches and an half high at its middle. This opening is the door of the fire-place; yet it is not intended for the same uses as the door of the fire-place in other furnaces; the purpose for which it is actually destined shall be explained when we come to shew how the furnace is to be used. An inch above the door of the fire-place, still in the fore-side of the furnace, are two holes of about an inch diameter, and at the distance of three inches and a half from each other, to which answer two other holes of the same size, made in the hinder part, directly opposite to these. There is moreover a fifth hole of the same width, about an inch above the door of the fire-place. The design of all these holes shall be explained when we describe the manner in which these furnaces are to be used.

Fourthly, the fore-part of the furnace is bound by three iron braces, one of which is fixed just below the door of the ash-hole; the second occupies the whole space between the ash-hole door and the door of the fire-place, and has two holes in it, answering to those which we directed to be made in the furnace itself about this place; and the third is placed immediately over the door of the fire-place. These braces must extend from one corner of the front of the furnace to the other, and be fastened thereto with iron pins, in such a manner that their sides next to the doors may

may not lie quite close to the body of the furnace, but form a kind of grooves for the iron plates to slide in, that are designed to shut the two doors of the furnace when it is necessary. Each of these iron plates should have a handle, by which it may be conveniently moved; and to each door there should be two plates, which meeting each other, and joining exactly in the middle of the door-place, may shut it very close. Each of the two plates belonging to the door of the fire-place ought to have a hole in its upper part; one of these holes should be a slit of about two lines wide, and half an inch long; the other may be a semi-circular opening of one inch in height and two in breadth. These holes should be placed so that neither of them may open into the fire-place when the two plates are joined together in the middle of the door to shut it close.

Fifthly, to terminate the furnace above, there must be a pyramid formed of the same materials with the furnace, hollow, quadrangular, three inches high on a base of seven inches, which base must exactly fit the upper opening of the furnace; the top of this pyramidal cover must end in a tube of three inches in diameter and two in height, which must be almost cylindrical, and yet a little inclining to the conical form. This tube serves, as in the furnaces already described, to carry the conical funnel, which is fitted to the upper part when a fire of extraordinary activity is wanted,

The furnace thus constructed is fit to serve all the purposes for which it is designed: yet before it can be used another piece must be provided, which, though it does not properly belong to the furnace, is nevertheless necessary in all the operations performed by it; and that is a piece contrived to contain the cupels, or other vessels which are to be

be exposed to the fire in this furnace. It is called a muffle, and is made in the following manner.

On an oblong square, of four inches in breadth, and six or seven in length, a concave semi-cylinder is erected, in the form of a vault, which makes a semi-circular canal, open at both ends. One of these is almost entirely closed, except that near the bottom two small semi-circular holes are left. In each of its sides likewise two such holes are made, and the other end is left quite open.

The muffle is intended to bear and communicate the fiercest heat; and therefore it must be made thin, and of an earth that will resist the violence of fire, such as that of which crucibles are made. The muffle being thus constructed, and then well baked, is fit for use.

When it is to be used it must be put into the furnace by the upper opening, and set upon two iron bars, introduced through the holes made for that purpose below the door of the fire-place. The muffle must be placed on these bars in the fire-place in such a manner that its open end shall stand next to, and directly against, the door of the fire-place, and may be joined to it with lute. Then the cupels are ranged in it, and the furnace is filled up, to the height of two or three inches above the muffle, with small coals not bigger than a walnut, to the end that they may lie closed round the muffle, and procure it an equal heat on every side. The chief use of the muffle is to prevent the coals and ashes from falling into the cupels, which would be very prejudicial to the operations carrying on in them: for the lead would not vitrify as it ought, because the immediate contact of the coals would continually restore its phlogiston; or else the glass of lead, which ought to penetrate and pass through the cupels, would be rendered incapable of so doing; because the ashes mixing therewith would give it such a consistence and tenacity as would destroy

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that property, or at least considerably lessen it. The openings, therefore, which are left in the lower part of the muffle, should not be so high as to admit coals or ashes to get into the cupels; the use of them is to procure an easier passage for the heat and the air to those vessels. The muffle is left quite open in its fore-part, that the operator may be at liberty to examine what passes in the cupels, to stir their contents, to remove them from one place to another, to convey new matters into them, &c. and also to promote the free access of the air, which must concur with the fire towards the evaporation necessary to the vitrification of lead; which air, if fresh were not often enough admitted, would be incapable of producing that effect; because it would soon be loaded with such a quantity of vapours that it could not take up any more.

The government of the fire in this furnace is founded on the general principles above laid down for all furnaces. Yet as there are some little differences, and as it is very essential to the success of the operations for which this furnace is intended, that the artist should be absolutely master of his degree of heat, we shall in few words shew how that may be raised or lowered.

When the furnace is filled with coals and kindled, if the door of the ash-hole be set wide open, and that of the fire-place shut very close, the force of the fire is encreased; and if moreover the pyramidal cover be put on the top, and the conical funnel added to it, the fire will become still more fierce.

Seeing the matters contained in this furnace are encompassed with fire on all sides, except in the fore part opposite to the door of the fire-place, and as there are occasions which require that the force of the fire should be applied to this part also, an iron box of the shape and size of the door, hath been contrived to answer that purpose. This box

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is filled with lighted coals, and applied immediately to the door-place, by which means the heat there is considerably augmented. This help may be made use of at the beginning of the operation, in order to accelerate it, and bring the heat sooner to the desired degree; or in case a very fierce heat be required; or at a time when the air being hot and moist will not make the fire burn with the necessary vigour.

The heat may be lessened by removing the iron-box, and shutting the door of the fire-place quite close. It may be still further and gradually diminished, by taking off the conical funnel from the top; by shutting the door of the fire-place with one of its plates only, that which has the least, or that which has the greatest aperture in it; by taking off the pyramidal cover; by shutting the ash-hole-door wholly or in part; and lastly, by setting the door of the fire-place wide open: but, in this last case, the cold air penetrates into the cavity of the muffle, and refrigerates the cupels more than is almost ever necessary. If it be observed, during the operation, that the muffle grows cold in any particular part, it is a sign there is a vacuity left by the coals in that place: in this case an iron wire must be thrust into the furnace, through the hole which is over the door of the fire-place, and the coals stirred therewith, so as to make them fall into their places and fill up the vacant interstices.

It is proper to observe that, besides what has been said concerning the ways of increasing the activity of the fire in the cupelling furnace, several other causes also may concur to procure to the matters contained in the muffle a greater degree of heat: for example, the smaller the muffle is, the wider and more numerous the holes in it are; the nearer to its bottom, or further end, the cupels are placed;

the more will the matters therein contained be affected with heat.

Besides the operations to be performed by the cupel, this furnace is very useful and even necessary, for many chymical experiments; such, for instance, as those relating to sundry vitrifications and enamelling. As it is pretty low, the best way is to place it, when it is to be used, on a base of brick-work that may raise it to a level with the operator's hand.

A lamp-furnace is exceeding useful for all operations that require only a moderate, but long continued, degree of heat. The furnace for working with a lamp heat is very simple: it consists only of a hollow cylinder, from fifteen to eighteen inches high, and five or six in diameter, having at its bottom an aperture large enough for a lamp to be introduced and withdrawn with ease. The lamp must have three or four wicks, to the end that by lighting more or fewer of them a greater or less degree of heat may be produced. The body of the furnace must moreover have several small holes in it, in order to supply the flame of the lamp with air enough to keep it alive.

On the top of this furnace stands a basin five or six inches deep, which ought to fill the cavity of the cylinder exactly, and to be supported at its circumference by a rim which may entirely cover and close the furnace: the use of this basin is to contain the sand through which the lamp-heat is usually conveyed.

Besides this there must be a kind of cover or dome made of the same material with the furnace, and of the same diameter with the sand-bath, without any other opening than a hole, nearly circular, cut in its lower extremity. This dome is a sort of reverberatory, which serves to confine the heat, and direct it towards the body of the retort; for it is used only when something is to be distilled in a vessel

vessel of this fashion; and then the hole at its bottom serves for a passage to the neck of the retort. This dome should have an ear or handle, for the conveniency of putting it on and taking it off with ease.

Of Lutes.

Chymical vessels, especially such as are made of glass, and the earthen vessels commonly called stoneware, are very subject to break when exposed to sudden heat or cold: whence it comes that they often crack when they begin to heat, and also when being very hot they happen to be cooled, either by fresh coals thrown into the furnace, or by the access of cold air. There is no way to prevent the former of these accidents, but by taking the pains to warm your vessel very slowly, and by almost insensible degrees. The second may be avoided by coating the body of the vessel with a paste or lute, which being dried will defend it against the attacks of cold.

The fittest stuff for coating vessels is a composition of fat earth, Windsor-loam, fine sand, filings of iron, or powdered glass, and chopped cow's hair, mixed and made into a paste with water. This lute serves also to defend glass vessels against the violence of the fire, and to prevent their melting easily.

In almost all distillations it is of great consequence, as hath been said, that the neck of the distilling vessel be exactly joined with that of the receiver into which it is introduced, in order to prevent the vapours from escaping into the air and so being lost: and this junction is effected by means of a lute.

A few slips of paper applied round the neck of the vessels with common size will be sufficient to

keep in such vapours as are aqueous, or not very spirituous.

If the vapours are more acrid, or more spirituous, recourse may be had to slips of bladder long steeped in water, which containing a sort of natural glue close the junctures of the vessels very well.

If it be required to confine vapours of a still more penetrating nature, it will be proper to employ a lute that quickly grows very hard; particularly a paste made with quick-lime and any sort of gelly, whether vegetable or animal; such as the white of an egg, stiff size, &c. This is an excellent lute and not easily penetrated. It is also used to stop any cracks or fractures that happen to glass vessels. But it is not capable of resisting the vapours of mineral acid spirits, especially when they are strong and smoking: for that purpose it is necessary to incorporate the other ingredients thoroughly with fat earth softened with water; and even then it frequently happens that this lute is penetrated by acid vapours, especially those of the spirit of salt, which of all others are confined with the greatest difficulty.

In such cases its place may be supplied with another, which is called a fat lute, because it is actually worked up with fat liquors. This lute is composed of a very fine cretaceous earth, called tobacco-pipe clay, moistened with equal parts of the drying oil of lint-seed, and a varnish made of amber and gum copal. It must have the consistence of a stiff paste. When the joints of the vessels are closed up with this lute, they may, for greater security, be covered over with slips of linen smeared with the lute made of quick-lime and the white of an egg.

Chymical vessels are liable to be broken in an operation by other causes besides the sudden application of heat or cold. It frequently happens that

the vapours of the matters exposed to the action of fire rush out with such impetuosity, and are so elastic, that finding no passage through the lute with which the joints of the vessels are closed, they burst the vessels themselves, sometimes with explosion and danger to the operator.

To prevent this inconvenience, it is necessary that in every receiver there be a small hole, which being stopped only with a little lute may easily be opened and shut again as occasion requires. It serves for a vent-hole to let out the vapours, when the receiver begins to be too much crowded with them. Nothing but practice can teach the artist when it is requisite to open this vent. If he hits the proper time, the vapours commonly rush out with rapidity, and a considerable hissing noise; and the vent should be stopped again as soon as the hissing begins to grow faint. The lute employed to stop this small hole ought always to be kept so ductile, that by taking the figure of the hole exactly it may entirely stop it. Besides, if it should harden upon the glass, it would stick so fast that it would be very difficult to remove it without breaking the vessel. This danger is easily avoided by making use of the fat lute, which continues pliant for a long time, when it is not exposed to an excessive heat.

This way of stopping the vent-hole of the receiver has yet another advantage: for if the hole be of a proper width, as a line and half, or two lines, in diameter, then when the vapours are accumulated in too great a quantity, and begin to make a great effort against the sides of the receiver, they push up the stopple, force it out, and make their way through the vent-hole: so that by this means the breaking of the vessels may always be certainly prevented. But great care must be taken that the vapours be not suffered to escape in this manner, except when absolute necessity requires it; for

for it is generally the very strongest and most subtle part of the liquor which is thus dissipated and lost.

Heat being the chief cause that puts the elasticity of the vapours in action, and prevents their condensing into a liquor, it is of great consequence in distillation that the receiver be kept as cool as possible. With this view a thick plank should be placed between the receiver and the body of the furnace, to intercept the heat of the latter, and prevent its reaching the former. As the vapours themselves rise very hot from the distilling vessel, they soon communicate their heat to the receiver, and especially to its upper part, against which they strike first. For this reason it is proper that linen cloths dipt in very cold water be laid over the receiver, and frequently shifted. By this means the vapours will be considerably cooled, their elasticity weakened, and their condensation promoted.

By what hath been said in this first part, concerning the properties of the principal agents in chymistry, the construction of the most necessary vessels and furnaces, and the manner of using them, we are sufficiently prepared for proceeding directly to the operations, without being obliged to make frequent and long steps, in order to give the necessary explanations on those heads.

Nevertheless we shall take every proper occasion to extend the theory here laid down, and to improve it by the addition of several particulars which will find their places in our Treatise of Chymical Operations.

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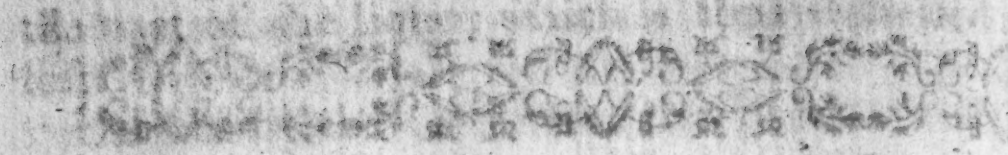
PRACTICE of CHYMISTRY.

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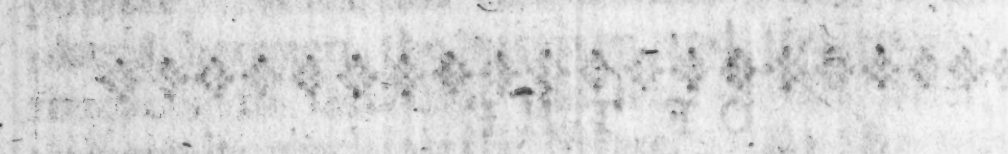
The Fundamental Operations are
described, and illustrated by Ob-
servations on each Process.



THE PRACTICE OF CHEMISTRY



BY J. L. EMMETT



IN TWO VOLUMES

VOLUME I

OF THE

PRACTICE OF CHEMISTRY

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IN TWO VOLUMES

VOLUME II

OF THE

PRACTICE OF CHEMISTRY

BY J. L. EMMETT

TO THE
LONDON
1743

ELEMENTS
OF THE
PRACTICE OF CHYMISTRY.

INTRODUCTION.

AS the Elements of the Theory of Chymistry, delivered in the former part of this work, were intended, for the use of persons supposed to be altogether unacquainted with the art, they could not properly admit of any thing more than fundamental principles, so disposed as constantly to lead from the simple to the compound, from things known to things unknown : for which reason I could not therein observe the usual order of chymical decomposition, which is not susceptible of such a method. I therefore supposed all the analyses made, and bodies reduced to their simplest principles; to the end that, by observing the chief properties of those primary elements, we might be enabled to trace them through their several combinations, and to form some sort of judgement *a priori* of the qualities of such compounds as may result from their junctions.

But this latter part is of a different nature. It is a Practical Treatise, intended to contain the manner

manner of performing the principal operations of chymistry; the operations which serve as standards for regulating all the rest, and which confirm the fundamental truths laid down in the theory.

As these operations consist almost wholly of analyses and decompositions, there can be no doubt concerning the order proper to be observed in giving an account of them: it evidently coincides with that of the analysis itself.

But as all bodies, which are the subjects of chymical operations, are divided by nature into three classes or kingdoms, the mineral, the vegetable, and the animal, the analysis thereof may naturally be divided into three branches: some difference may also arise from the different order in which these three may be treated of.

As the reasons assigned for beginning with one kingdom rather than with another have never been thoroughly canvassed, and may perhaps seem equally good when viewed in a particular light, chymical writers differ in their opinions on this point. For my part, without entering into a discussion of the motives which have determined others to follow a different order, I shall only produce the reasons that led me to begin with the mineral kingdom, to examine the vegetable in the second place, and to conclude with the animal.

First then, seeing vegetables draw their nourishment from minerals, and animals derive theirs from vegetables, the bodies which constitute these three kingdoms seem to be generated the one by the other, in a manner that determines their natural rank.

Secondly, this disposition procures us the advantage of tracing the principles, from their source in the mineral kingdom, down to the last combinations into which they are capable of entering, that is, into animal matters; and of observing the successive

cessive alterations they undergo in passing out of one kingdom into another.

Thirdly and lastly, I look upon the analysis of minerals to be the easiest of all; not only because they consist of fewer principles than vegetables and animals, but also because almost all of them are capable of enduring the most violent action of fire, when that is necessary to their decomposition, without any considerable change or diminution of their principles, to which those of other substances are frequently liable.

Besides, I am not singular in this distribution of the three classes of bodies, which are the subjects of the chymical analysis: as it is the most natural, it has been adopted by several authors, or rather by most who have published treatises of chymistry. But there is something peculiarly my own in the manner wherein I have treated the analysis of each kingdom. In the mineral kingdom, for instance, will be found a considerable number of operations not to be met with in other treatises of chymistry; the authors having probably considered them as useless, or in some measure foreign to the purpose of elementary books, and as constituting together a distinct art. I mean the processes for extracting saline and metallic substances from the minerals containing them.

Yet, if it be considered that salts, metals, and semi-metals are far from being produced by nature in a state of perfection, or in that degree of purity which they are commonly supposed to have when they are first treated of in books of chymistry; but that, on the contrary, these substances are originally blended with each other, and adulterated with mixtures of heterogeneous matters, wherewith they form compound minerals; I imagine it will be allowed that the operations by which these minerals are decomposed, in order to extract the metals, semi-metals, and other simpler substances, especially

as they are founded on the most curious properties of these substances, are so far from being useless or foreign to the purposes of an elementary treatise, that they are, on the contrary, absolutely necessary thereto.

After I had made these reflections, I could not help thinking that an analysis of minerals, which should treat of saline and metallic substances, without taking any notice of the manner in which their matrices must be analysed, in order to extract them, would be no less defective, than a treatise of the analysis of vegetables, in which oils, essential salts, fixed and volatile alkalis, should be amply treated of, without saying one word of the manner of analysing the plants from which these several substances are obtained. I therefore thought myself indispensably obliged to describe the manner of decomposing every ore or mineral, before I attempted to treat of the saline or metallic substance which it yields.

For example: as the vitriolic acid, with the consideration of which I begin my mineral analysis, is originally contained in vitriol, sulphur, and alum; and as these substances again derive their origin from the sulphureous and ferruginous Pyrites, the first operations I describe under this head are the processes for decomposing the pyrites in order to extract its vitriol, sulphur, and alum. I then proceed to the particular analysis of each of these substances, with a view to extract their vitriolic acid; and afterwards deliver, in their order, the other operations usually performed on this acid. Thus it appears that this saline substance occasions my describing the analyses of the pyrites, vitriol, sulphur, and alum. The whole of the treatise on minerals proceeds on the same plan.

The operations by which we decompose ores and minerals are of two sorts: those employed in working by the great, and those for trying in small the

yield

yield of any ore. These two manners of operating are sometimes a little different; yet in the main they are the same, because they are founded on the same principles, and produce the same effects.

As my chief design was to describe the operations that may be conveniently performed in a laboratory, I have preferred the processes for small assays; especially as they are usually performed with more care and accuracy than the operations in great works: and here I must acknowledge that I am obliged to M. Cramer's *Docimasia*, or Art of Assaying, for all my operations of this kind in my analysis of minerals. As M. Hellot's work on that subject did not appear till after I had finished this, M. Cramer's *Docimasia*, in which sound theory is joined with accurate practice, was the best book of the kind I could at that time consult. I therefore preferred it to all others; and as I have not quoted it in my analysis of minerals, because the quotations would have been too frequent, let what I say here serve for a general quotation. I have been careful to name, as often as occasion required, the other authors whose processes I have borrowed: it is a tribute justly due to those who have communicated their discoveries to the public.

Though I have told the reader that in my analysis of minerals he will find the processes for extracting out of each the saline or metallic substances contained in it, yet he must not expect that this book will instruct him in all that it is necessary he should know to be able to determine, by an accurate assay, the contents of every mineral. My intention was not to compose a treatise of assaying; and I have taken in no more than was absolutely necessary to make the analysis of minerals perfectly understood, and to render it as complete as it ought to be in an elementary treatise. I have therefore described only the principal operations relating thereto; the operations which are fundamental, and which, as I said

said before, are to serve as standards for the rest, abstracted from such additional circumstances as are of consequence only to the art of assaying, properly so called.

Such therefore as are desirous of being fully instructed in that art, must have recourse to those works which treat professedly of the subject; and particularly to that published by M. Hellot: a performance most esteemed by such as are best skilled in chymistry, and rendered so complete by the numerous and valuable observations and discoveries of the author, that nothing better of the kind can be wished for. I thought it proper to give these notices in relation to my analysis of minerals; and shall now proceed to shew the plan of my analyses of vegetables and of animals.

Seeing all vegetable matters are susceptible of fermentation, and when analysed after fermentation, yield principles different from those we obtain from them before they are fermented, I have divided them into two classes; the former including vegetables in their natural state, before they have undergone fermentation; and the latter those only which have been fermented. This analysis opens with the processes by which we extract from vegetables all the principles they will yield without the help of fire; and then follow the operations for decomposing plants by degrees of heat, from the gentlest to the most violent, both in close vessels and in the open air.

I have not made the same division in the animal kingdom, because the substances that compose it are susceptible only of the last degree of fermentation, or putrefaction; and moreover the principles they yield, whether putrefied or unputrefied, are the very same, and differ only with regard to their proportions, and the order in which they are extricated during the analysis.

I begin this analysis with an examination of the milk

milk of animals that feed wholly on vegetables; because though this substance be elaborated in the body of the animal, and by that means brought nearer to the nature of animal matters, yet it still retains a great similitude to the vegetables from which it derives its origin, and is a sort of intermediate substance between the vegetable and animal. Then I proceed to the analysis of animal matters properly so called, those which actually make a part of the animal body. I next examine the excrementitious substances, that are thrown out of the animal body as superfluous and useless. And then I conclude this latter part with operations on the volatile alkali; a saline substance of principal consideration in the decomposition of animal matters.

Though, in the general view here given of the order observed in this treatise of Practical chymistry, I have mentioned only such processes as serve for analysing bodies, yet I have also inserted some other operations of different kinds. The book would be very defective if it contained no more: for the design of chymistry is only to analyse the mixts produced by nature, in order to obtain the simplest substances of which they are composed, but moreover to discover by sundry experiments the properties of those elementary principles, and to recombine them in various manners, either with each other, or with different bodies, so as to reproduce the original mixts with all their properties, or even form new compounds which never existed in nature. In this book therefore the reader will find processes for combining and recombining, as well as for resolving and decomposing bodies. I have placed them next to the processes for decomposition, taking all possible care not to interrupt their order, or break the connection between them.

IN THE COURT OF COMMONS



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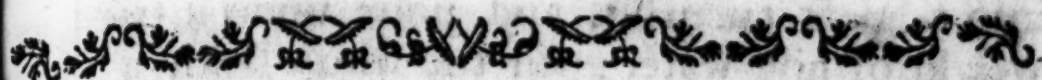
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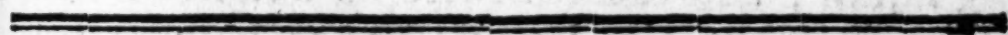


P A R T I.
O F M I N E R A L S.



S E C T I O N I.

Operations performed on Saline Mineral Substances.



C H A P. I.

Of the VITRIOLIC ACID.



P R O C E S S I.

To extract Vitriol from the Pyrites.

TAKE any quantity you please of iron-pyrites; leave them for some time exposed to the air: they will crack, split, lose their brightness, and fall into powder. Put this powder
into

into a glass cucurbit, and pour upon it twice its weight of hot water; stir the whole with a stick, and the liquor will grow turbid. Pour it, while it is yet warm, into a glass funnel lined with brown filtering paper; and having placed your funnel over another glass cucurbit, let the liquor drain into it. Pour more hot water on the powdered pyrites, filter as before, and so go on, every time lessening the quantity of water, till that which comes off the pyrites appears to have no astringent vitriolic taste.

Put all these waters together into a glass vessel that widens upwards; set it on a sand-bath, and heat the liquor till a considerable smoke arises; but take care not to make it boil. Continue the same degree of fire till the surface of the liquor begins to look dim, as if some dust had fallen into it; then cease evaporating, and remove the vessel into a cool place: in the space of four and twenty hours will be formed therein a quantity of crystals, of a green colour and a rhomboidal figure: these are vitriol of Mars, or copperas. Decant the remaining liquor; add thereto twice its weight of water; filter, evaporate, and crystallize as before; repeat these operations till the liquor will yield no more crystals, and keep by themselves the crystals obtained at each crystallization.

OBSERVATIONS.

The pyrites are minerals, which, by their weight and shining colours, frequently impose on such as are not well acquainted with ores. At first sight they may be taken for very rich ones; and yet they consist only of a small quantity of metal combined with much sulphur or arsenic, and sometimes with both.

They strike fire with a steel as flints do, and emit a sulphureous smell: so that they may be known by

by this extemporaneous proof. The metal most commonly and most abundantly found in the pyrites is iron; the quantity whereof sometimes equals, or even exceeds, that of the sulphur. Besides metallic and sulphureous matters, the pyrites contain also some unmetallic earth.

There are several sorts of pyrites: some of them contain only iron and arsenic. They have not all the property of efflorescing spontaneously in the air, and turning into vitriol: none do so but such as consist only of iron and sulphur, or at least contain but a very small portion of copper, or of arsenic: and even amongst those that are composed of iron and sulphur alone, there are some that will continue for years together exposed to the air without shooting, and indeed without suffering the least sensible alteration.

The efflorescence of the iron-pyrites, and the changes they undergo, are phenomena well worth our notice. They depend on the singular property which iron possesses of decomposing sulphur by the help of moisture. If very fine iron-filings be accurately mingled with flowers of sulphur, this mixture, being moistened with water, grows very hot, swells up, emits sulphureous vapours, and even takes fire: what remains is found converted into vitriol of Mars. On this occasion, therefore, the sulphur is decomposed; its inflammable part is dissipated or consumed; its acid combines with the iron, and a vitriol arises from that conjunction.

This is the very case with the pyrites that consist only of iron and sulphur; yet some of them, as we said before, do not effloresce spontaneously and turn to vitriol. The reason probably is, that, in such minerals, the particles of iron and sulphur are not intimately mixed together, but separated by some earthy particles.

In order to procure vitriol from pyrites of this kind, they must be for some time exposed to the action

action of fire, which by consuming part of their sulphur, and rendering their texture less compact, makes way for the air and moisture, to which they must be afterwards exposed, to penetrate their substance, and produce in them the changes with which those others are affected that germinate spontaneously.

The pyrites which contain copper and arsenic, and for that reason do not effloresce, must likewise undergo the action of fire; which besides the effects it produces on pyrites that consist of iron and sulphur only, dissipates also the greatest part of the arsenic. These pyrites being first roasted, and then exposed to the air for a year or two, do also yield vitriol; but then it is not a pure vitriol of iron, but is combined with a portion of blue vitriol, the basis of which is copper.

Sometimes also there is alum in the vitriolic waters drawn off the pyrites. It was on account of this mixture of different salts that we recommended the keeping apart the crystals obtained from each different crystallization: for by this means they may be examined separately, and the species to which they belong discovered.

When vitriol of iron is adulterated with a mixture of the vitriol of copper only, it is easy to purify it and bring it to be entirely martial, by dissolving it in water, and setting plates of iron in the solution: for iron having a greater affinity than copper with the vitriolic acid, separates the latter from it, and assuming its place produces a pure vitriol of Mars.

In large works for extracting vitriol from the pyrites they proceed thus. They collect a great quantity of pyrites on a piece of ground exposed to the air, and pile them up in heaps of about three foot high. There they leave them exposed to the action of the air, sun, and rain, for three years together; taking care to turn them every six months,

months, in order to facilitate the efflorescence of those which at first lay undermost. The rain-water which has washed those pyrites is conveyed by proper channels into a cistern; and when a sufficient quantity thereof is gathered, they evaporate it to a pellicle in large leaden boilers, having first put into it a quantity of iron, some part of which is dissolved by the liquor, because it contains a vitriolic acid that is not fully saturated therewith. When it is sufficiently evaporated, they draw it off into large leaden or wooden coolers, and there leave it to shoot into crystals. In these last vessels several sticks are placed, crossing each other in all manner of directions, in order to multiply the surfaces on which the crystals may fasten.

The pyrites are not the only minerals from which vitriol may be procured. All the ores of iron and copper that contain sulphur may also be made to yield green or blue vitriol, according to the nature of each, by torrefying them, and leaving them long exposed to the air: but this use is seldom made of them, as there is more profit to be got by extracting the metals they contain. Besides, it is easier to obtain vitriol from the pyrites, than from those other mineral substances.

PRO-

PROCESS H.

To extract Sulphur from the Pyrites, and other sulphureous Minerals.

Reduce to a coarse powder any quantity of yellow pyrites, or other mineral containing sulphur. Put this powder into an earthen or glass retort, having a long wide neck, and so large a body that the matter may fill but two thirds of it. Set the retort in a sand-bath fixed over a reverberating furnace: fit to it a receiver half full of water, and so placed that the nose of the retort may be about an inch under the water: give a gradual fire, taking care you do not make it so strong as to melt the matter. Keep the retort moderately red for one hour, or an hour and half, and then let the vessels cool.

Almost all the sulphur separated by this operation from its matrix will be found at the extremity of the neck of the retort, being fixed there by the water. You may get it out either by melting it with such a gentle heat as will not set it on fire, or by breaking the neck of the retort.

OBSERVATIONS.

OF all minerals the Pyrites contain the most sulphur; those especially which have the colour of fine brass, a regular form such as round, cubical, hexagonal, and, being broken, present a number

of shining needles, all radiating, as it were, from a center.

A very moderate heat is sufficient to separate the sulphur they contain. We directed that the retort employed should have a long and wide neck, with a view to procure a free passage for the sulphur: the water set in the receiver detains the sulphur, fixes it, and prevents it from flying off: so that it is unnecessary to close the joints of the vessels. But it is proper to take notice that whenever you use an apparatus for distilling, which requires the beak of the retort to be under water, it is of very great consequence that the fire be constantly so regulated that the retort may not cool in the least; for in that case, as the rarefied air contained therein would be condensed, the water in the receiver would rise into the retort and break it.

If in distilling sulphur, according to the present process, the matter contained in the retort should happen to melt, the operation would be thereby considerably protracted, and it would require a great deal more time to extract all the sulphur; because all evaporation is from the surface only, and the matter, while it remains in a coarse powder, presents a much more extensive surface than when it is melted.

This remark holds with regard to all other distillations. Any quantity of liquor, set to distil in its fluid state, will take much more time to rise in vapours, and pass from the retort into the receiver, than if it be incorporated with some solid body reduced to minute parts, so that the whole shall make a moist powder; and this though the very same degree of fire be applied in both cases.

If the matter from which it is proposed to extract sulphur be such as will melt with the degree of fire necessary to this operation: that is with a heat which will make the retort but faintly red, it must be mixed with some substance that is not so

fusible. Very pure coarse sand, or clean gravel, may be used with success; but absorbent earths are altogether improper for this purpose, but they will unite with the sulphur.

The sulphurous minerals which are most apt to fuse are the cupreous pyrites, or yellow copper ores: common lead ores are also very fusible.

The pyrites are by this operation deprived of almost all the sulphur they contain; and consequently little is left behind, but the particles of iron and copper, together with a portion of un-metallic earth, which we shall shew how to separate from these metals, when we come to treat of them. I say that, by this operation, the pyrites are deprived of almost all, and not entirely of all their sulphur; because, this separation being made in close vessels only, there always remains a certain quantity of sulphur, which adheres so obstinately to the metals, that it would be almost impossible to get it all out, even though a much stronger fire than that directed in the process were applied for this purpose, and though choice had been, as it ought to be, made of such pyrites, or other sulphurous minerals, as part most easily with their sulphur. Nothing but a very strong fire in the open air is capable of carrying it wholly off, or consuming it entirely.

In several places are found great quantities of native sulphur. The volcanos abound with it, and people gather it at the foot of those burning mountains. Several springs of mineral waters also yield sulphur, and it is sometimes found sublimed to the vaulted roofs of certain wells, and among others in one at Aix la-Chapelle.

The Germans and Italians have large works, for extracting sulphur in quantities out of pyrites, and other minerals which abound therewith. The process they work by is the same with that here delivered; but with this difference only, that sulphur

being but of small value they do not use so many precautions. They content themselves with putting the sulphureous minerals into large crucibles, or rather earthen cucurbits, which they place in the furnace in such a manner that, when the sulphureous part melts, it runs into vessels filled with water, and is thereby fixed.

The sulphur obtained, either by distillation or by simple fusion, is not always pure.

When it is obtained by distillation, if the matters from which you extract it contain moreover some other minerals of nearly the same volatility, such, for instance as arsenic, or mercury, these minerals will come over with it. This is easily perceived: for pure sublimed sulphur is always of a beautiful yellow, inclining to a lemon colour. If it looks red, or have a reddish cast, it is a sign that some arsenic hath risen along with it.

Mercury sublimed with sulphur likewise gives it a red colour; but sulphur is very seldom adulterated with this metallic substance; for arsenic is frequently found combined with the pyrites, and other sulphureous minerals; whereas, on the contrary, we very rarely meet with any mercury in them.

But if mercury should happen to rise with the sulphur in distillation, it may be discovered by examining the sublimate; which, in that case, will have the properties of cinabar: on being broken its inside will appear to consist of needles adhering laterally to each other; its weight will be very considerable; and lastly, the great heat of the place where it is collected will furnish another mark to know it by; for, as cinabar is less volatile than arsenic or sulphur, it fastens on places too hot for either sulphur or arsenic to bear.

Sulphur may also be adulterated with such fixed matters, either metallic or earthy, as it may have carried up along with it in the distillation, or as

may have been sublimed by the arsenic, which has a still greater power than sulphur to volatilize fixed bodies.

If you desire to free the sulphur from most of these heterogeneous matters, it must be put into an earthen cucurbit, and set in a sand bath. To the cucurbit must be fitted one or more aludels, and such a degree of heat applied as shall but just melt the sulphur; which is much less than that necessary to separate the sulphur from its matrix. As soon as the sulphur is melted it will sublime in lemon-coloured flowers, that will stick to the insides of the aludels.

When nothing more appears to rise with this degree of heat, the vessels must be suffered to cool. At the bottom of the cucurbit will be found a sulphureous mass, containing the greatest part of the adventitious matters that were mixed with the sulphur, and more or less red or dark-coloured, according to the nature of those matters.

When we come to treat of Arsenic and Mercury, we shall give the methods of separating sulphur entirely from those metallic substances.

PROCESS III.

To extract Alum from aluminous Minerals.

TAKE such minerals as are known or suspected to contain alum. Expose them to the air, that they may effloresce. If they remain there a year without any sensible change, calcine them, and then leave them exposed to the air, till a bit thereof being put on the tongue imparts an astringent aluminous taste.

When

When your matters are thus prepared, put them into a leaden or glass vessel; pour upon them thrice their weight of hot water; boil the liquor; filter it; and repeat these operations till the earth be so edulcorated that the water which comes off it hath no taste. Mix all these solutions together, and let them stand four and twenty hours, that the gross and earthy parts may settle to the bottom; or else filter the liquor: then evaporate till it will bear a new-laid egg. Now let it cool, and stand quiet four and twenty hours: in that time some crystals will shoot, which are most commonly vitriolic; for alum is rarely obtained by the first crystallization. Remove these vitriolic crystals: if any crystals of alum be found amongst them, these must be dissolved anew, and set to crystallize a second time in order to their purification; because they partake of the nature as well as of the colour of vitriol. By this method extract all the alum that the liquor will yield.

If you get no crystals of alum by this means, boil your liquor again, and add to it a twentieth part of its weight of a strong alkaline lixivium, or a third part of its weight of putrefied urine, or a small quantity of quick-lime. Experience and repeated trials must teach you which of these three substances is to be preferred, according the particular nature of the mineral on which you are to operate. Keep your liquor boiling, and if there be any alum in it, there will appear a white precipitate: in that case let it cool and settle. When the white precipitate is entirely fallen, decant the clear, and leave the crystals of alum to shoot at leisure, till the liquor will yield no more: it will then be exceeding thick.

OBSERVATIONS.

Alum is obtained from several sorts of minerals. In some parts of Italy, and in sundry other places, it effloresces naturally on the surface of the earth. There it is swept together with brooms, and thrown into pits full of water. This water is impregnated therewith till it can dissolve no more. Then it is filtered, and set to evaporate in large leaden vessels; and when it is sufficiently evaporated, and ready to shoot into crystals, it is drawn off into wooden coolers, and there left for the salt to crystallize.

In aluminous soils there are often found springs strongly impregnated with alum; so that to obtain it the water need only be evaporated.

In the country about Rome there is a very hard stone, which is hewn out of the quarry just like other stones for building: this stone yields a great deal of alum. In order to extract it, the stones are calcined for twelve or fourteen hours; after which they are exposed to the air in heaps, and carefully watered three or four times a day for forty days together. In that time they begin to effloresce, and to throw out a reddish matter on their surface. Then they are boiled in water, which dissolves all the alum they contain, and being duly evaporated gives it back in crystals. This is the alum called *Roman alum*.

Several sorts of pyrites also yield a great deal of alum. The English have a stone of this kind, which in colour is very like a slate. This stone contains much sulphur, which they get rid of by roasting it. After this they steep the calcined stone in water, which dissolves the alum it contains, and to this solution they add a certain quantity of lye made of the ashes of sea-weeds.

The

The Swedes have a pyrites of a bright, golden colour, variegated with silver spots, from which they procure sulphur, vitriol, and alum. They separate from it the sulphur and the vitriol by the methods above prescribed. When the liquor which hath yielded vitriol is become thick, and no more vitriolic crystals shoot in it, they add an eighth part of its weight of putrefied urine, mixed with a lye made of the ashes of green wood. Upon this there appears and falls to the bottom a copious red sediment. They decant the liquor from this precipitate, and when it is duly evaporated find it shoot into beautiful crystals of alum.

What hath been said, concerning the several matrices from which alum is obtained, sufficiently shews that it is seldom solitary in the waters with which aluminous subjects have been lixiviated. It is almost always accompanied with a certain quantity of vitriol, or other saline mineral matters, which obstruct its crystallization, and prevent its being pure. 'Tis with a view to free it from these matters, that the waters impregnated with alum are mixed with a certain quantity of the lye of some fixed alkali, or with putrefied urine, which contains much volatile alkali. These alkalis have the property of decomposing all the neutral salts which have for their basis either an absorbent earth or a metallic substance; and such as have a metallic substance for their basis more readily than those whose basis is an earth. Consequently, if they are mixed with a liquor in which both these sorts of salts are dissolved, they must decompose that sort whose basis is metallic sooner than the other whose basis is an earth. This is what comes to pass in a solution of alum and vitriol. The metallic part of the latter is separated from its acid by the alkalis, when mixed with that solution; and it is this metallic part, which is generally iron, that appears in the

the form of a redish precipitate, as above mentioned.

But because alkalis decompose also those neutral salts which have an earth for their basis, care must be taken that too much thereof be not added; else what you put in, more than is necessary to decompose the vitriolic salts in your liquor, will attack the alum, and decompose it likewise.

The alkali made use of to promote the crystallization of the alum joins with the vitriolic acid, which had dissolved the substances now precipitated, and therewith forms different neutral salts according to its particular nature. If the alkali be a lixivium of common wood-ashes, the neutral salt will be a vitriolated tartar; if a lixivium of the ashes of a maritime plant like soda, the neutral salt will be a Glauber's salt; if putrified urine, the neutral salt will be a vitriolic ammoniacal salt. Some of these salts incorporate with the alum, which in large works crystallizes in vast lumps; and hence it comes that some sorts of alum when mixed with a fixed alkali smell like a volatile alkali.

The crystals of alum are octaedral, that is, they are solids with eight sides. These octaedral solids are triangular pyramids, having their angles cut away, so that four of their surfaces are hexagons, and the other four triangles.

Sulphur, vitriol, and alum, are the three principal subjects in which we certainly know that the universal or vitriolic acid particularly resides, and from which we extract it when we want to have it pure. For this reason we thought it proper, before we treated of the extraction of this acid, to shew the method of separating those matters themselves from the other minerals out of which we obtain them.

crystallized

Moreover,

Moreover, all the other matrices, in which the vitriolic acid is most commonly lodged, may be referred to one or other of the matters which serve as bases to these three minerals.

To sulphur we may refer all combinations of the vitriolic acid with an inflammable matter: but we must take care not to confound sulphur with those bitumens in which the vitriolic acid may be found: for the basis of those bitumens is a real oil; whereas the basis of sulphur is the pure phlogiston. Yet as oils themselves contain the phlogiston, which in union with the vitriolic acid forms a true sulphur, it follows that such bitumens may in a certain respect be classed with sulphur.

The same is to be said of vitriol. The name is usually given to such combinations only as are formed of the vitriolic acid with iron or copper, which make the green and blue vitriol; and to a third species of vitriol, which is white, and has zinc for its basis: but as the vitriolic acid may, by particular combinations, be united with many other metallic substances, all such metallic salts must be referred to the class of vitriols.

The same may also be said of alum, which is no other than a combination of the vitriolic acid with a particular kind of absorbent earth; so that all combinations of this acid with any earth whatever may be placed in the same class.

This last class of mixts is the most extensive of all that contain the vitriolic acid; because there are a vast many earths all differing from one another, with which that acid may be united. Alum properly so called, the gypsums, talcs, selenites, boles, and all the other compounds of this kind, differ from each other only in their particular earths.

The different properties of these earthy salts depend on the nature of their bases. Those which are of the aluminous kind retain much water in crystallizing,

crystallizing, which makes them very soluble in water, and gives them the property of acquiring readily the aqueous fluor when exposed to the fire. Those which are of the nature of the selenites admit but very little water in their crystals, and consequently are almost insoluble in water; nor does the fire give them an aqueous fluor. Lastly, the gypsums and talcs are still more destitute of these properties. The natures of the earths in these several compounds are hitherto but very imperfectly known, and may give the chymists occasion for enquiries equally curious and useful.

The vitriolic acid is sometimes found complicated with a fixed alkaline basis. This is almost always the alkali of sea-salt, so that the compound is a Glauber's salt. Some mineral waters are impregnated therewith; which happens when these waters contain vitriol or alum, together with sea-salt.

From the principles laid down, in our Elements of the Theory, it appears that the vitriolic acid hath not so great an affinity with earthy and metallic substances as with fixed alkalis; and also that it is stronger than the marine acid, and hath a greater affinity with fixed alkalis. This being allowed, the generation of native Glauber's salts is easily accounted for. The acid of aluminous or vitriolic salts quits the earth or the metal with which it was combined, and expelling the acid of sea-salt unites with its basis. Warmth greatly promotes these decompositions.

If the common fossil salt, usually called *sal gem*, or any other kind of sea-salt, should happen to be near a vulcano, when it discharges flaming sulphur, as is frequently the case, and if this sulphur should run among the sea-salt, a Glauber's salt would instantly be formed in that place; because when sulphur burns, its acid is separated and set at liberty.

Lastly, if aluminous or vitriolic matters, or burn-

ing sulphur, should meet with the ashes of plants or trees consumed by fire, a vitriolated tartar would be formed, because these ashes contain a fixed alkali of the same nature with that of tartar.

The vitriolic acid when combined with an earthy basis adheres strongly thereto; so that the force of fire is able to expel very little or none of it. There is no way of separating it from such a basis, but by presenting to it an alkaline salt, with which it will unite: nor is it ever extracted from such matters when it is required pure. It does not adhere so firmly to metallic substances; but is separated from them by the force of fire: so that it may be obtained from the several sorts of vitriol. It is usually drawn from green vitriol; that being the commonest sort.

As to sulphur, the phlogiston which is its basis being the substance wherewith the vitriolic acid hath the greatest affinity, it would be altogether impossible to decompose it, and to separate its acid, if it were not inflammable; but by burning it the phlogiston is destroyed, and leaves the acid at liberty. By this means therefore it may be separated. We shall now give the processes for extracting the acid from vitriol and sulphur.

PROCESS IV.

To extract the Vitriolic Acid from Green Vitriol.

TAKE any quantity of green vitriol: put it in an unglazed earthen vessel, and heat it gradually. Vapours will soon begin to rise. Encrease the fire a little, and it will liquify by means of the water contained in it, and acquire what we called an aqueous fluor. Continue the calcination, and it will become less and less fluid, grow thick, and turn of

of a greyish colour. Now raise your fire, and keep it up till the salt recover its solidity, acquire an orange colour, and begin to grow red where it immediately touches the sides of the vessel. Then take it out, and reduce it to powder.

Put the vitriol thus calcined and pulverized into a good earthen retort, of which one half at least must remain empty. Set the retort in a reverberatory furnace: fit thereto a large glass receiver, and, having luted the joint well, give fire by degrees. You will soon see white clouds rise into the receiver, which will render it opaque, and heat it. Continue the same degree of fire till these clouds disappear: they will be succeeded by a liquor which will trickle down the sides of the receiver in veins. Still keep up the fire to the same degree as long as these veins appear. When they begin to abate, encrease the fire, and push it to the utmost extremity: upon this, there will come over a black, thick liquor: it will even be found congealed, and prove the icy oil of vitriol, if care hath been taken to change the receiver, keep the vessels perfectly close, and give a sufficient degree of heat. Proceed thus till nothing more comes over, or at least very little. Let the vessels cool, unlute them, pour the contents of the receiver into a bottle, and seal it hermetically.

OBSERVATIONS.

Green vitriol retains much water in crystallizing and in order to free it from that superfluous phlegm, it must be calcined before you distil it. Without this precaution the operation will be exceedingly protracted, and a great deal of time wasted in distilling such a quantity of water; which will moreover greatly weaken the acid by commixing with it, unless care be taken to change the recipient as soon as the water is all come over.

But there is also another advantage in calcining the vitriol before you put it into the retort: for otherwise this salt would melt on the first application of heat, and run into a mass; which would prove a great hindrance to its distillation. This inconvenience is avoided by a previous calcination, in consequence whereof the vitriol is easily reduced to a powder which never becomes fluid.

Vitriol calcined as directed in the process grows so hard, and adheres so firmly to the vessel in which the calcination is performed, that it requires no small pains to separate and pulverize it. Care must be taken to put it into the retort as soon as it is pulverized, and to stop that vessel very close if you do not begin the distillation immediately: for otherwise it will naturally attract from the air almost all the moisture it hath lost.

The acid which vitriol yields by distillation is sulphureous; probably because it still retains some of the phlogiston, with which it was united when under the form of sulphur in the pyrites; or else hath laid hold on a portion of that belonging to the iron which served for its basis in vitriol. But this sulphureous part is volatile, and flies off in time.

This decomposition of vitriol in close vessels is a difficult and laborious process. To carry the operation to its utmost perfection requires a fire of extreme violence, kept up without intermission during four or five days; such in short as few vessels are able to bear. Of course this operation is seldom performed in laboratories. The French chymists fetch their oil of vitriol from Holland, where it is extracted from vitriol in large quantities, by means of furnaces erected for the purpose, in which many retorts are employed at once.

In the Memoirs of the Academy of Sciences M. Hellot hath given us the most material circumstances of a very fine experiment of this kind, in which

he pushed the distillation of green vitriol to the utmost. Into a German retort * he put six pounds of green English vitriol calcined to redness, which he exposed to a fire of the extremest violence, constantly kept up during four days and four nights. At the expiration of that time he found in the vessels employed as receivers an icy oil of vitriol, which was altogether in a crystalline form and black. The precautions necessary to make this experiment succeed he represents in the following terms.

“ The success of this operation, which produces
 “ an oil of vitriol perfectly icy and without any li-
 “ quor, depends on the care taken to prevent the
 “ acid vapours, driven by the fire out of vitriol
 “ calcined to redness, from having any communi-
 “ cation with the external air while they are distil-
 “ ling : for otherwise they will attract from it a
 “ moisture which will keep them fluid in the re-
 “ ceiver. The receiver must be at such a distance
 “ from the furnace that it may remain cool enough
 “ for the vapours to condense in it. There must
 “ also be sufficient room for those vapours to cir-
 “ culate in, and to prevent the sulphureous explo-
 “ sions, which are every now and then discharged
 “ out of the retort, from bursting the vessels : for
 “ though the previous calcination of the vitriol
 “ hath carried off the most volatile, yet there still
 “ remains enough of the inflammable principle
 “ even in the iron itself, to form a sulphur with
 “ the acid as it is extricated, or at least a mixt that
 “ would be as apt to take fire as common sulphur
 “ if it were not over-dosed with the acid.

“ As the best means of gaining these ends, M
 “ Hellot contrived to adapt to the neck of his re-
 “ tort a receiver with two necks, the lowermost of
 “ which was inserted into a large ballon. Receiver

* They are much the best, and bear a very fierce heat.

“ applied to each other in this manner are called
“ adopters.

“ It is no easy matter to get this icy oil out of
“ the ballon : for as soon as the air touches it such
“ a thick cloud of sulphureous fumes arises, that
“ it is absolutely necessary to place the vessel on
“ some shelf over head, because a man cannot stand
“ exposed thereto for a single minute without be-
“ ing suffocated.”

This icy acid must be shut up with all possible
expedition in a crystal bottle accurately closed with
a glass stopple, which should be ground with emery
in its neck so as to fit it exactly : for it attracts
moisture so powerfully, that, unless exceeding great
care be taken to prevent all communication with
the external air, it will soon dissolve into a fluid.

“ The icy oil is black ; because the acid vapours
“ carry over with them something of a greasy mat-
“ ter, from which vitriol is seldom free, and which
“ always appears, after repeated solutions and cry-
“ stallizations of this salt, in the mother-water
“ which will shoot no more. Now the smallest
“ portion of inflammable matter presently blackens
“ the most highly rectified oil of vitriol, which is
“ perfectly clear.

“ The vitriolic acid, when forced over by a vio-
“ lent heat, carries along with it some ferruginous
“ particles also, that want nothing but to be united
“ with a phlogiston to become true iron. They
“ are easily discovered, either in the common black
“ oil of vitriol, or in the blackish crystals of the
“ icy oil, by only dissolving them in a large quan-
“ tity of distilled water : for after seven or eight
“ days digestion a light powder or downy sediment
“ precipitates, which being calcined in a violent
“ fire is partly attracted by the magnet ; and being
“ again calcined with bees-wax becomes almost en-
“ tirely iron.”

The *caput mortuum* of this distillation of vitriol

is the ferruginous earth of this salt, and is called *colcothar*. When this *colcothar* hath undergone a violent fire, as in the experiment now related, scarce any acid remains therein. Out of six pounds of vitriol that M. Hellot used, he could recover no more, by lixiviating what was left in the retort, than two ounces of a vitriolic salt; and even that was very earthy.

If vitriol be exposed to a fire neither so violent nor so long continued, its *colcothar* will yield a greater quantity of vitriol that hath not been decomposed. A white crystalline salt is also obtained from it, and called *Salt of Colcothar*; which is no other than the small portion of alum usually contained in vitriol, and not so easily decomposed by the action of fire.

PROCESS V.

To decompose sulphur, and extract its acid, by burning it.

TAKE any quantity of the purest sulphur: fill therewith a crucible or other earthen dish: heat it till it melts: then set it on fire; and when its whole surface is lighted place it under a large glass head, taking care that the flame of the sulphur do not touch either its sides or bottom; that the air have free access, in order to make the sulphur burn clear; and that the head incline a little toward the side on which its beak is, that as the vapours condense therein the liquor may run off with ease. To the beak of this vessel fit a receiver: the fumes of the

the lighted sulphur will be condensed, and gather into drops in the head, out of which they will run into the receiver. There, when the sulphur has done burning, you will find an acid liquor, which is the spirit of sulphur.

OBSERVATIONS.

In the burning of sulphur, the phlogiston which serves for its basis is dissipated, and separated from the acid which is left at liberty. The acid fumes which rise from the lighted sulphur strike against the inside of the head placed over it, are there condensed, and appear in the form of a liquor. But as sulphur, like all other inflammable bodies, nitre excepted, will not burn in close vessels, it is necessary that the air be freely admitted here: which occasions the loss of a great deal of the acid of the sulphur, as is evident from the pungent suffocating smell perceived in the laboratory during the operation.

This acid, while combined with the phlogiston, is incapable of contracting any union with water; but when alone is very apt to mix therewith: it is even proper to put some in its way, that it may incorporate therewith as soon as it is discharged from the sulphur; for then it is very free from phlegm, very volatile, and consequently very little disposed to condense into a liquor, but on the contrary very apt to fly off in vapours. The water, which it imbibes with a kind of avidity, fixes and detains it; so that by this means a much greater quantity thereof is obtained from sulphur, than if it were distilled without this precaution.

It is proper, therefore, now and then to introduce a dish full of hot water under the head which receives the fumes of the sulphur. The vapours that exhale from the water bedew the inside of the

the head, and procure the advantage we are speaking of.

The same thing may be effected several other ways: thus, the crucible containing the sulphur may be set on a foot placed in an earthen dish with some water in it; which however must not rise above the foot; for if it should reach the crucible, it might cool and fix the sulphur. The dish thus prepared must be placed on a sand-bath hot enough to make the water smoke continually; and over all is to be placed the head as directed in the process.

The size and form of the vessel which immediately receives the sulphureous fumes, may also contribute to increase the quantity of the acid spirit. A very large vessel, with a hole at bottom no wider than is just sufficient to admit the vapours, is the properest for this operation.

After the sulphur has burnt for some time, it often happens that a sort of skin or crust forms on its surface, which is not inflammable, but gradually lessens the quantity and vigour of the flame as it increases in thickness, and at last puts it quite out. This crust proceeds from the impurities, and heterogeneous uninflammable particles contained in the sulphur. Care must be taken to remove it with an iron wire as fast as it forms.

Two quantities of sulphur may also be kept in two crucibles, and heated alternately. That in which the sulphur is hot and melted may be substituted for the other in which the sulphur is grown cold and fixed; because cold sulphur does not burn well.

The spirit of sulphur is at first pungent and volatile, because it still retains a small portion of the phlogiston: but that sulphureous part flies off, especially if the bottle in which the spirit is kept be left for some time unstopped.

The acid obtained from sulphur appears by alchemical

chymical proofs perfectly like that obtained from vitriol: they differ in this only that the former is the purest; for the acid obtained from vitriol carries over with it some metallic parts, as we observed before, which can never happen to that obtained from sulphur.

If linen rags dipped in a solution of fixed alkali be exposed to the fumes of burning brimstone, the spirit of sulphur joins with the alkali, and therewith forms a vitriolated tartar. This salt is known to be formed when the rags grow stiff, and appear spangled with a vast many glittering points, which are nothing but little crystals of the salt we are speaking off.

When the sulphur burns very gently and slowly, the spirit that exhales from it is so much the more sulphureous and volatile: and hence the salt formed by the combination of this spirit with the alkali exposed to it in linen rags, as in the above mentioned experiment, is not at first a vitriolated tartar; but a neutral salt of a particular kind, which is capable of being decomposed by any other mineral acid, the sulphureous acid having less affinity than any of the rest with alkalis. Nevertheless this salt becomes in time a true vitriolated tartar, because the sulphureous part which weakened its acid, easily quits it and flies off.

PRO-

PROCESS VI.

To concentrate the vitriolic acid.

TAKE the vitriolic acid you intend to concentrate, that is, to dephlegmate and make stronger: pour it into a good glass retort, of such a size that your quantity of acid may but half fill it: set this retort in the sand-bath of a reverberating furnace: fit to it a receiver; lute it on, and give a gradual fire. There will come over into the receiver a clear liquor, the first drops of which will be but faintly acid: this is the most aqueous part.

When the drops begin to follow one another much more slowly, raise your fire, till the liquor begin to bubble a little in the middle. Keep it thus gently boiling, till one half or two thirds thereof be come over into the receiver. Then let your vessels cool; unlute them; what remains in the retort pour into a crystal bottle, and stop it exactly with a glass stopple rubbed with emery.

OBSERVATIONS.

The acid obtained from sulphur is generally very aqueous; either because in preparing it water must necessarily be administered, that it may unite therewith as it separates from the sulphur; or because it is so greedy of moisture as to attract a great deal from the air, which must needs be admitted to make the sulphur burn.

The acid obtained from vitriol, excepting that which rises last, is also mixed with a pretty considerable

derable quantity of phlegm; because the vitriol, though calcined, still retains a great deal thereof, which rises with the acid in distillation. Now, as there are many chymical experiments that will not succeed without acids exceedingly dephlegmated, it is proper to have in a laboratory all the acids thus conditioned; because if they happen to be too strong for particular operations, as is sometimes the case, it is very easy to lower them to the desired degree, by adding a sufficient quantity of water.

The vitriolic acid is much heavier and much less volatile than water. If therefore a mixture of these two liquors be exposed to the fire, the aqueous part will rise with a degree of heat which is not able to carry up the acid: by this means they may be separated from each other; and thus is the vitriolic acid concentrated.

Nevertheless, as this acid combines most closely with water, and is in a manner strongly connected with it, the water carries up some portion thereof along with it; and hence it comes that the liquor which rises into the receiver is acid: it is called *Spirit of vitriol*.

As the fire carries off the most aqueous part, the other which remains in the retort increases in specific gravity. The acid particles are brought nearer together, retain the aqueous particles more obstinately; and therefore to separate them the degree of heat must be increased.

It is usual to draw off one half or two thirds of the liquor that was put into the retort: but this depends on the degree of strength the acid was of before concentration, and the degree of concentration intended to be given it.

If the acid to be concentrated be oil of vitriol, from being brown or black it grows clearer as the operation advances, and at last becomes perfectly colourless and transparent; because the fat matter,

ter, which tinged it black, is dissipated during the process. Some of it deposits a white crystalline earth.

A sulphureous smell is generally perceived about the vessels in this operation. This arises from a small portion of the phlogiston from which the acid is not free; and it is this inflammable matter which gives the oil of vitriol its black colour: for the clearest and best rectified oil of vitriol will become brown, and even black, in a short time, if any inflammable matter, though in a very small quantity, be dissolved therein.

The vessels are luted in this operation, to prevent any loss of the spirit of vitriol, which being very acid is of use in many chymical experiments, and may itself also be again concentrated.

We observed that in this operation it is necessary the retort should be of very good glass. Indeed the acid is so active and so strong, that if the glass be tender and have a little too much salt in its composition, it will be so corroded thereby that it will fall to pieces.

Though we directed the retort to be set in a sand-bath for this operation, it does not follow that it may not also be placed in a naked fire: on the contrary, when the heat is not conveyed through a bath the operation advances faster, and is much less tedious. But then great caution must be used, and the closest attention given to the management of the fire, which must be raised by almost imperceptible degrees, especially at the beginning of the operation; otherwise it is next to a certainty that the vessels will break. In general, a naked fire may be employed in almost all distillations which require a greater degree of heat than that of boiling water, or the *balneum mariae*: the operation will be sooner finished; but it requires an experienced hand, that has by practice acquired a habit of governing the fire with judgement.

There

There is moreover another advantage in not using the sand-bath; which is, that if in the time of the operation you perceive the fire too fierce, you can quickly check it, either by stopping close all the apertures of the furnace, or by drawing out all or part of the lighted coals. This inconvenience is not near so easily remedied when you use the sand-bath; because when once heated it retains its heat very long after the fire is quite extinguished.

PROCESS VII.

To decompose vitriolated Tartar by means of the Phlogiston; or to compose Sulphur by combining the vitriolic Acid with the Phlogiston.

TAKE equal parts of vitriolated tartar, and very dry salt of tartar, separately reduced to powder; add an eighth part of their weight of charcoal-dust; and mix the whole together very accurately. Throw this mixture into a red hot crucible, placed in a furnace filled with burning coals. Cover it very close, and keep it very hot, till the mixture melt, which may be known by uncovering the crucible from time to time. There will then appear a blueish flame, accompanied with a pungent smell of sulphur.

Take the crucible out of the fire: dissolve its contents in hot water: filter the solution through brown paper supported by a glass funnel: drop in to the filtered liquor by little and little any acid whatever. As you add the acid the liquor will grow more and more turbid, and let fall a grey precipitate.

precipitate. Continue dropping in more acid till the liquor will yield no more precipitate. Filter it a second time, to separate it from the precipitate; what remains on the filter is a true inflammable sulphur, which you may either melt or sublime into flowers.

OBSERVATIONS.

All bodies that contain the vitriolic acid may contribute, as well as vitriolated tartar, to the generation of sulphur: so that all the neutral salts in which this acid is a principle, the alums, felenites, gypsums, vitriols, may be substituted for it in this experiment. All these matters, with the addition of charcoal-dust only, being fused in a crucible, constantly produce sulphur; because the vitriolic acid having a greater affinity with the phlogiston than with any thing else, will quit its basis, whatever it be, to join with the phlogiston of the charcoal, and therewith form a sulphur.

The fixed alkali added thereto helps to promote the fusion of the ingredients, which is necessary for effecting the desired combination. It also serves to unite with the sulphur, when formed; and thus makes the combination called *liver of sulphur*, which prevents the sulphur from being consumed as soon as formed: for the fixed alkalis, which are combustible, hinder sulphur from burning so easily as it would do if they were not joined with it. They may afterwards be separated from each other, by the means of any acid whatever.

This process, in which sulphur is regenerated by re-combining together the principles of which it was originally composed, is one of the most beautiful experiments that modern chymistry hath produced. We are indebted for it to M. Stahl; and Dr. Geoffroy hath given a particular account of it in the Memoirs of the academy of sciences.

Before

Before these gentlemen Glauber and Boyle had indeed published methods of producing sulphur, Glauber made use of his *sul mirabile* and powdered charcoal: Boyle employed the vitriolic acid and oil of turpentine. But neither of those chymists understood the true theory of their operations: they did not thoroughly know the principles of sulphur: they did not imagine they had composed sulphur; they thought they only extracted what they supposed to exist previously in the matters they employed in their experiments.

M. Stahl was the first who discovered and explained the nature of sulphur, and proved that in Glauber's and Boyle's experiments sulphur was actually produced, by uniting together the principles of which it is constituted. This beautiful experiment gives the strongest lustre of evidence to the theory of the composition of that mixt, which acts such a capital part in chymistry; and it can no longer be doubted that sulphur is actually a combination of the vitriolic acid with the phlogiston.

Besides this important truth, our process for composing sulphur by art proves several others that are equally essential and fundamental.

The first is that the vitriolic acid hath a greater affinity with the phlogiston than with any other thing, seeing it quits metallic and earthy substances, as well as alkaline salts, in order to combine therewith.

The second is that sulphur combines with fixed alkalis without suffering any decomposition; seeing it may be separated from them entire and unaltered; and seeing that very sulphur, which is naturally indissoluble in water, is rendered soluble therein by the union it hath contracted with the fixed alkali.

The third is that the vitriolic acid, which when it is pure hath the greatest affinity with alkalis of any acid whatever, loses a great deal of that affinity

ty by contracting an union with the phlogiston: seeing the weakest acids are capable of decomposing the liver of sulphur, and separating the sulphur from the alkali. And this also confirms one of the general propositions concerning affinities advanced in our theory; to wit, that the affinities of compound or mixed substances are weaker than those of the same substances in a purer or more simple state.



C H A P. II.

Of the NITROUS ACID.

P R O C E S S I.

To extract nitre out of nitrous earths and stones. The purification of salt-petre. Mother of nitre. Magnesia.

TAKE any quantity of nitrous earths or stones reduce them to powder; and therewith mix third part of the ashes of green-wood and quicklime. Put this mixture into a barrel or vat, and pour on it hot water to about twice the weight of the whole mass. Let it stand thus for twenty four hours, stirring it from time to time with a stick. Then filter the liquor through brown paper, and pass it through a flannel-bag, till it come clear: will then have a yellowish colour. Boil this liquor and evaporate till you perceive that a drop of it let fall on any cold body coagulates. Then stop the evaporation, and set your liquor in a cool place.

place. In the space of four and twenty hours crystals will be formed in it, the figure of which is that of an hexagonal prism, having its opposite planes generally equal, and terminated at each extremity by a pyramid of the same number of sides. These crystals will be of a brownish colour, and de-
 flagrate on a live-coal.

Decant the liquor from these crystals; mix it with twice its weight of hot water; evaporate and crystallize as before. Repeat the same operation till the liquor will yield no more crystals: it will then be very thick, and goes by the name of *Mother of nitre*.

OBSERVATIONS.

Earths and stones that have been impregnated with animal or vegetable juices susceptible of putrefaction, and have been long exposed to the air, but sheltered from the sun and rain, are those which yield the greatest quantity of nitre. But all sorts of earths and stones are not equally fit to produce it. None is ever found in flints or sands of a crystalline nature.

Some earths and stones abound so with nitre, that it effloresces spontaneously on their surface, in the form of a crystalline down. This nitre may be collected with brooms, and accordingly has the name of *Salt-petre sweepings*. Some of this sort is brought from India.

Hitherto we are much in the dark as to the origin and generation of nitre. Some chymists pretend that the nitrous acid is diffused through the air, and gradually deposited in such earths and stones as are qualified to receive it.

Others, considering that none of it is ever obtained but from earths that have been impregnated with vegetable or animal juices, have from thence concluded those two kingdoms to be the general repositories of the nitrous acid; that if we do not perceive

perceive it to exist in such matters at all, or at least in any great quantity, till they have undergone putrefaction, and are in some measure incorporated with suitable earths and stones, it is because the acid is so entangled with heterogeneous particles that it requires the assistance of putrefaction, and much more of filtration through an earth, to disengage it, and enable it to appear in its proper nature.

Lastly, others are of opinion that this acid is no other than the universal or vitriolic acid; disguised indeed by a portion of the phlogiston, which is combined with it in a peculiar manner by the means of putrefaction. They ground this opinion chiefly on the analogy or resemblance which they find between the nitrous acid and the volatile sulphureous spirit. Its volatility, its pungent smell, its properties of taking fire, and of destroying the blue and violet colours of vegetables, serve them as so many proofs.

Their opinion is the more probable on this account, that even though the nitrous acid should actually be produced by vegetable and animal substances, yet as these substances themselves draw all their component principles from the earth, and as the vitriolic acid is diffused through all the soils which afford them nourishment, there is great reason to think that the nitrous acid is no other than the vitriolic acid altered by the changes and combinations it hath undergone in its passage into and through those substances. In 1750 the royal academy of sciences at Berlin proposed an account of the generation of nitre as the subject for their prize, which was conferred on a memoir wherein this last opinion was supported by some new and very judicious experiments.

The process by which our salt-petre makers extract nitre in quantities, out of rubbish and nitrous earths, is very nearly the same with that here set

down:

down: so that I shall not enter into a particular account of it. I shall only take notice of one thing, which it is of some consequence to know; namely, that there is no nitrous earth which does not contain sea-salt also. The greatest quantities of this salt are to be found in those earths which have been drenched with urine, or other animal excrements. Now, as the rubbish of old houses in great cities is in this class, it comes to pass that when the salt-petre workers evaporate a nitrous lixivium drawn from that rubbish, as soon as the evaporation is brought to a certain pitch, a great many little crystals of sea-salt form in the liquor, and fall to the bottom of the vessel.

The salt-petre workers in France call these saline particles *the grain*, and take great care to separate them from the liquor, (which as long as it continues hot keeps the salt-petre dissolved) before they set it to crystallize. This fact seems a little singular, considering that sea-salt dissolves in water more easily than salt petre, and crystallizes with more difficulty.

In order to discover the cause of this phenomenon we must recollect some truths delivered in our theoretical elements. The first is, that water can keep but a determinate quantity of any salt in solution, and that if water fully saturated with a salt be evaporated, a quantity of salt will crystallize in proportion to the quantity of water evaporated. The second is, that those salts which are the most soluble in water, particularly those which run in the air, will dissolve in cold and in boiling water equally; whereas much greater quantities of the other salts will dissolve in hot and boiling water than in cold water. These things being admitted, when we know that sea-salt is one of the first sort, and salt-petre of the second, the reason why sea-salt precipitates in the preparation of salt-petre appears at once. For,

When the solution of salt-petre and sea-salt comes to be evaporated to such a degree that it contains as much sea-salt as it possibly can, this salt must begin to crystallize, and continue to do so gradually as the evaporation advances. But because at the same time it does not contain as much salt-petre as it can hold, seeing it is capable of dissolving a much greater quantity thereof when it is boiling hot than when it is cold, this last named salt will not crystallize so soon. If the evaporation were continued till the case of the salt-petre came to be the same with that of the sea-salt, then the salt-petre also would begin to crystallize gradually in proportion to the water evaporated, and the two salts would continue crystallizing promiscuously together: but it is never carried so far; nor is it ever necessary; for as the water cools it becomes more and more incapable of holding in solution the same quantity of salt-petre as when it was boiling hot.

And then comes the very reverse, with regard to the crystallizing of the two salts; for then the salt-petre shoots, and not the sea-salt. The reason of this fact is also founded on what has just been said. The sea-salt, of which cold water will dissolve as much as boiling water, and which owed its crystallizing before only to the evaporation, now ceases to crystallize as soon as the evaporation ceases; while the salt-petre, which the water kept dissolved only because it was boiling hot, is forced to crystallize merely by the cooling of the water.

When the solution of salt-petre has yielded as many crystals of that salt as it can yield by cooling, it is again evaporated, and being then suffered to cool yields more crystals. And thus they continue evaporating and crystallizing, till the liquor will afford no more crystals. It is plain, that as the salt-petre crystallizes, the proportion of sea-salt to the dissolving liquor increases; and as a certain quantity

quantity of water evaporates also during the time employed in crystallizing the salt-petre, a quantity of sea-salt, proportioned to the water so evaporating, must crystallize in that time; and this is the reason why salt-petre is adulterated with a mixture of sea-salt. It likewise follows that the last crystals of nitre, obtained from a solution of salt-petre and sea-salt, contain much more sea-salt than the first.

From all that has been said concerning the crystallization of salt-petre and sea-salt, it is easy to deduce the proper way of purifying the former of these two salts from a mixture of the latter. For this purpose the salt-petre to be refined need only be dissolved in fair water. The proportion between the two salts in this second solution is very different from what it was in the former; for it contains no more sea-salt than what had crystallized along with the salt-petre under favour of the evaporation, the rest having been left dissolved in the liquor that refused to yield any more nitrous crystals.

As there is therefore a much greater quantity of salt-petre than of sea-salt in this second solution, it is easy to evaporate it to such a degree that a great deal of salt-petre shall crystalize, while much more of the water must necessarily be evaporated before any of the sea-salt will crystallize.

However, the salt-petre is not yet entirely freed from all mixture of sea-salt by this first purification; for the crystals obtained from this liquor, in which sea-salt is dissolved, are still encrusted, and, as it were, infected therewith: hence it comes, that, to refine the salt-petre thoroughly, these crystallizations must be repeated four or five times.

The salt-petre men commonly content themselves with crystallizing it thrice, and call the produce salt-petre of the first, second, or third shoot, according to the number of crystallizations it has undergone. But their best refined salt-petre, even that

that of the third shooting, is not yet sufficiently pure for chymical experiments that require much accuracy: so that it must be further purified; but still by the same method.

The nitrous acid is not pure in the earths and stones from which it is extracted. It is combined partly with the very earth in which it is formed, and partly with the volatile alkali produced by putrefaction of the vegetable or animal matters that concurred to its generation. A fixed alkali and quick-lime are added to the lixivium of a nitrous earth, in order to decompose the nitrous salt formed in that earth, and to separate the acid from the volatile alkali and the absorbent earth with which it is united: thence comes that copious sediment which appears in the lye at the beginning of the evaporation. These matters form with that acid a true nitre, much more capable than the original nitrous salts of crystallization, detonation, and the other properties which are essential thereto. The basis of nitre is therefore a fixed alkali mixed with a little lime.

The mother of nitre, which will yield no more crystals, is brown and thick; by evaporation over a fire it is further inspissated, and becomes a dry, solid body; which however being left to itself soon gives, and runs into liquor. This water still contains a good deal of nitre, sea-salt, and the acids of these salts united with an absorbent earth. It contains moreover a great deal of a fat, viscid matter, which prevents its crystallizing.

All saline solutions in general, after having yielded a certain quantity of crystals, grow thick, and refuse to part with any more, though they still contain much salt. They are all called *mother-waters*, as well as that which hath yielded nitre. The mother-waters of different salts may prove the subjects of curious and useful enquiries.

If a fixed alkali be mixed with the mother of nitre, a copious white precipitate immediately falls, which being collected and dried is called *Magnesia*. This precipitate is nothing but the absorbent earth that was united with the nitrous acid, together with a good deal of the lime that was added, and was also united with that acid, from which they are now separated by the fixed alkali, according to the usual laws of affinities.

The vitriolic acid poured upon mother of nitre causes many acid vapours to rise, which are a compound of the nitrous and marine acids, that is, an *aqua regia*. On this occasion also there falls a large quantity of a white powder, which is still called *Magnesia*; yet it differs from the former in that it is not, like it, a pure absorbent earth, but combined with the vitriolic acid.

An *aqua regis* may also be drawn from nitrous earths by the force of fire only, without the help of any additament.

PROCESS II.

*To decompose Nitre by means of the Phlogiston. Vi-
tre fixed by Charcoal. Clyffus of Nitre. Sal
Polychrestum.*

TAKE the purest salt-petre in powder; put it into a large crucible, which it may but half fill; set the crucible in a common furnace, and surround it with coals. When it is red-hot the nitre will melt, and become as fluid as water. Then throw into the crucible a small quantity of charcoal dust: the nitre and the charcoal will immediately

diately deflagrate with violence; and a great commotion will be raised, accompanied with a considerable hissing, and abundance of black smoke. As the charcoal wastes, the detonation will abate, and cease entirely as soon as the coal is quite consumed.

Then throw into the crucible the same quantity of charcoal-dust as before, and the same phenomena will be repeated. Let this coal also be consumed: then add more, and go on in the same manner till you can excite no further deflagration; always observing to let the burning coal be entirely consumed before you add any fresh. When no deflagration ensues, the matter contained in the crucible will have lost much of its fluidity.

OBSERVATIONS.

Nitre will not take fire, unless the inflammable matter added to it be actually burning, or the nitre itself red-hot, and so thoroughly ignited as immediately to kindle it. Therefore, if you would procure the detonation of nitre with charcoal, and make use of cold charcoal, as in the process, the nitre in the crucible must be red-hot, and in perfect fusion: but you may also use live coals, and then the nitre need not be red-hot.

It is proper that the crucible used in this experiment should be only half full; for during the detonation its contents swell, and might run over without this precaution. For the same reason the charcoal-dust is to be thrown in by little and little; and that first put in must be entirely consumed before any fresh be added.

The matter remaining in the crucible after the operation is a very strong fixed alkali. Being exposed to the air it quickly attracts the moisture thereof, and runs into a liquor. It is called *alkalized nitre*, or to distinguish it from nitre alkalized

zated by other inflammable matters, *nitre fixed by charcoal.*

However, this alkali is not absolutely pure. It still contains a portion of the nitre that hath not been decomposed: for when there remains but a little of this salt mixed with a great quantity of alkali, which is not inflammable, the alkali in some measure shelters it, coats it over, and obstructs that immediate contact with the inflammable matters applied, which is necessary to make it deflagrate.

If the fixed alkali be desired perfectly free from any mixture of undecomposed nitre, the fire about the crucible must be considerably increased as soon as the detonation is entirely over; the matter must be made to flow, which requires a much stronger heat than would melt nitre, and kept thus in fusion for about an hour. After this no perfect nitre will be found therein: for the little that was left, being unable to abide the force of the fire, as not being extremely fixed, either is entirely dissipated, or loses its acid, which is carried off by the violence of the heat.

Fixed nitre contains also a portion of the earth that constituted the basis of the nitre, which is no other than the lime employed in its crystallization, or else some of the earth with which its acid was originally combined, and which it retained in crystallizing. When nitre is deflagrated with such matters as produce ashes, these ashes likewise furnish a certain quantity of earth, which mixes with the fixed alkali. To separate these several earths from the alkali, nothing more is requisite than to let it run *per deliquium*, or to dissolve it in water, and filter the solution through brown paper. Whatever is saline will pass through the filtre with the water, and the earthy part will be left upon it.

The nitrous acid is not only dissipated during the deflagration of the nitre, but is even destroyed
and

and perfectly decomposed. The smoke that rises during the operation has not the least odour of an acid. Its nature may be accurately examined by catching it in proper vessels, and condensing it into a liquor.

Nitre differs from sulphur, and from all other inflammable bodies whatever, in this, that the free access of the air is indispensably necessary to make any of the others burn; whereas nitre, and nitre only, is capable of burning in close vessels: and this property furnishes us with the means of collecting the vapours which it discharges in deflagration.

For this purpose, to a tubulated earthen retort you must fit two or three large adapters: set the retort in a furnace; and under it make a fire sufficient to keep its bottom moderately red. Then take a small quantity, two or three pinches for example, of a mixture of three parts of nitre with one of charcoal-dust, and drop it into the retort through its tube, which must be uppermost, and immediately stopped close. A detonation instantly ensues, and the vapours that rise from the inflamed mixture of nitre and charcoal, passing out through the neck of the retort into the adapters circulate therein for a while, and at last condense into a liquor.

When the detonation is over, and the vapour condensed, or nearly so, drop into the retort another equal quantity of the mixture; and repeat this till you find there is liquor enough in the recipient to be examined with ease and accuracy. This liquor is almost insipid, and shews no tokens of acidity, or at most but very slight ones. It is called *clyffu* of nitre.

It is easy to perceive why several adapters are required in this experiment, and why a very small quantity of the mixture must be introduced into the retort at once. The explosion, and the quantity

ity of air and vapours discharged on this occasion, would quickly burst the vessels, if all these precautions were not attended to. This plainly appears from the terrible effects of gun powder, which is nothing but a composition of nitre, sulphur, and charcoal.

Nitre is also decomposed and takes fire by the means of sulphur; but the circumstances and the result differ widely from those produced therewith by charcoal, or any other inflammable body.

Nitre deflagrates with sulphur an account of the phlogiston which the latter contains. If one part of sulphur be mixed with two or three parts of nitre, and the mixture thrown by little and little into a red-hot crucible, upon every projection there arises a detonation accompanied with a vivid flame.

The vapours discharged on this occasion have the mingled smell of a sulphureous spirit and spirit of nitre; and if they be collected by means of a tubulated retort, and such an apparatus of vessels as was used in the preceding experiment, the liquor contained in the recipients is found to be an actual mixture of the acid of sulphur, the sulphureous spirit, and the acid of nitre; the first being in greater quantity than the other two, and the second greater than the last.

Nor is the remainder after detonation a fixed alkali, as in the former experiments; but a neutral salt, consisting of the acid of sulphur combined with the alkali of nitre; a sort of vitriolated tartar known in medicine by the name of *sal polychrestum*.

There are evidently two essential differences between this last experiment and the preceding one. What remains after the deflagration of nitre with sulphur is not a fixed alkali: and moreover, the vapours emitted in the operation are impregnated with a quantity of the nitrous acid; which is not

the case when nitre is decomposed by any other inflammable matter which contains no vitriolic acid.

The reason of these differences is naturally deducible from what hath been already said concerning the properties of the vitriolic and nitrous acids. We have seen that by burning sulphur its acid is not decomposed, but only separated from its phlogiston. We also know that its acid has a great affinity with fixed alkalis. These things being granted, it follows that, as soon as the nitrous acid quits its alkaline basis, by deflagrating with the phlogiston of the sulphur, the acid of this very sulphur, being set at liberty by that deflagration, must unite with the alkaline basis deserted by the acid of nitre, and therewith form a neutral salt. Hence, instead of a fixed alkali, we find at the end of the operation a sort of vitriolated tartar; the acids of sulphur and of vitriol being the same, as is evident from what hath been above said concerning them.

In order to discover the cause of the other phenomenon, we must recollect two things advanced in our Elements of the Theory; to wit, that the affinity of the vitriolic acid with fixed alkalis is greater than that of the nitrous acid; and again, that the nitrous acid is not capable of combining and taking fire with the phlogiston, but when it is in the form of a neutral salt, that is, when it is united with some alkaline, earthy, or metallic basis. If these two principles be applied to the effect in question, the solution is easy and natural. For in the deflagration of nitre with sulphur, the phlogiston is not the only substance capable of separating the nitrous acid from its basis: the acid of the sulphur, more and more of which is set at liberty as the phlogiston is consumed, is also capable of producing the same effect; but with this difference, that the portion of the nitrous acid which is de-

tached

ached from its alkali by the phlogiston, is at the same instant set on fire and decomposed by that union; whereas the portion thereof which is separated by the vitriolic acid, being when so separated incapable of uniting with the phlogiston, and of consuming therewith, is preserved entire, and rises in vapours, together with that portion of the vitriolic acid which could not unite with the basis of the nitre.

P R O C E S S III.

*To decompose Nitre by means of the Vitriolic Acid.
The Smoking Spirit of Nitre. Sal de duobus. The
Purification of Spirit of Nitre.*

TAKE equal parts of well purified nitre and green vitriol; dry the nitre thoroughly, and bruise it to a fine powder. Calcine the vitriol to redness: reduce it likewise to a very fine powder; and mingle these two substances well together. Put the mixture into an earthen long-neck, or a good glass retort coated, of such a size that it may be but half full.

Set this vessel in a reverberating furnace covered with its dome; apply a large glass receiver, having a small hole in its body, stopped with a little lute. Let this receiver be accurately luted to the retort with the fat lute, and the joint covered with a slip of canvas smeared with lute made of quicklime and the white of an egg. Heat the vessels very gradually. The receiver will soon be filled with very dense red vapours, and drops will begin to distil from the nose of the retort.

Continue the distillation, encreasing the fire a little when you observe the drops to follow each other

but slowly, so that above two thirds of a minute passes between them; and, in order to let out the redundant vapours, open the small hole in the receiver from time to time. Towards the end of the operation raise the fire so as to make the retort red. When you find that, even when the retort is red-hot, nothing more comes over, unlute the receiver, and without delay pour the liquor it contains into a crystal bottle, and close it with a crystal stopple ground in its neck with emery. This liquor will be of a reddish yellow colour, smoking exceedingly, and the bottle containing it will be constantly filled with red fumes like those observed in the receiver.

OBSERVATIONS.

The vitriolic acid having a greater affinity with fixed alkalis than with any other substance, the phlogiston excepted, and being in the vitriol united with a ferruginous basis, will naturally quit that basis to join with the fixed alkali of the nitre; the acid whereof being weaker than the vitriolic, as we have already observed on several occasions, must needs be thereby expelled from its basis. The nitre therefore is decomposed by the vitriol, and its acid being set at liberty, is carried up by the force of the fire.

Indeed the nitrous acid, being thus separated from its alkaline basis, might be expected to combine with the ferruginous basis of the vitriol: but as it has, like all other acids, much less affinity with metallic substances than with alkalis, even a moderate degree of fire is sufficient to separate it from them. Moreover, this acid hath either no effect, or very little, upon iron that has lost much of its phlogiston by contracting an union with any acid; which is the case of the ferruginous basis of vitriol.

By the process here delivered, a very strong, perfectly dephlegmated, and vastly smoking spirit of nitre is obtained. If the precautions of drying the nitre and calcining the vitriol be neglected, the acid that comes over, greedily attracting the water contained in these salts, will be very aqueous, will not smoke, and will be almost colourless, with a very slight tinge of lemon.

The fumes of highly concentrated spirit of nitre, such as that obtained by the above process, are light, corrosive, and very dangerous to the lungs; being no other than the most dephlegmated part of the nitrous acid. The person therefore who unlutes the vessels, or pours the liquor out of the receiver into the bottle, ought with the greatest caution to avoid drawing them in with his breath; and for that reason ought to place himself so that a current of air, either natural or artificial, may carry them off another way. It is also necessary that care be taken, during the operation, to give the vapours a little vent every now and then, by opening the small hole in the recipient; for they are so elastic, that, if too closely confined, they will burst the vessels.

When the operation is over, you will find a red mass at the bottom of the retort, cast as it were in a mould. This is a neutral salt of the nature of vitriolated tartar, resulting from the union of the acid of the vitriol with the alkaline basis of the nitre.

The ferruginous basis of the vitriol, which is mixed with this salt, gives it the red colour. To separate it therefrom, you must pulverize it, dissolve it in boiling water, and filter the solution several times through brown paper; because the ferruginous earth of the vitriol is so fine, that some of it will pass through the first time. When the solution is very clear, and deposits no sediment, let it be set to shoot, and it will yield crystals of vitriolated tartar;

tar ; to which chymists have given the peculiar title of *sal de duobus*.

- In this *caput mortuum* we frequently find, besides the ferruginous earth of vitriol, a portion of nitre and vitriol not decomposed ; either because the two salts were not thoroughly mingled, or because the fire was not raised high enough towards the end of the operation.

Nitre may also be decomposed, and its acid obtained, by the interposition of any of the other vitriols, alums, gypsums, boles, clays ; in short, by means of any compound in which the vitriolic acid is found, provided it have not a fixed alkali for its basis.

The distillers of *aqua fortis*, who make large quantities at a time, and who use the least chargeable methods, do their business by the means of earthen vessels impregnated with the vitriolic acid ; such as clays and boles. With these earthen vessels they accurately mix the nitre from which they intend to draw their spirit : this mixture they put into large oblong earthen pots, having a very short curved neck, which enters a recipient of the same matter and form. These vessels they place in two rows opposite to each other in long furnaces, and cover them over with bricks cemented with Windsor-loam, which serves for a reverberatory : then they light the fire in the furnace, making it at first very small, only to warm the vessels ; after which they throw in wood, and raise the fire till the pots grow quite red-hot, in which degree they keep it up till the distillation is entirely finished.

The acid of nitre may also be separated from its basis by means of the pure vitriolic acid. For this purpose the nitre from which you mean to extract the acid must be finely pulverized, put into a glass retort, and a third of its weight of concentrated oil of vitriol poured on it : the retort must be placed in a reverberating furnace, and a receiver

like

like that used in the preceding operation, expeditiously applied.

As soon as the oil of vitriol touches the nitre, the mixture grows hot, and copious red fumes begin to appear: some drops of the acid come over even before the fire is kindled in the furnace.

On this occasion the fire must be moderate; because the vitriolic acid, being clogged by no basis, acts upon the nitre much more briskly, and with much greater effect, than when it is not pure.

This operation may be performed by a sand heat; which is a speedy and commodious way of obtaining the nitrous acid. In other respects the precautions recommended in the preceding experiment must be carefully observed here, both in distilling the acid and in taking it out of the receiver.

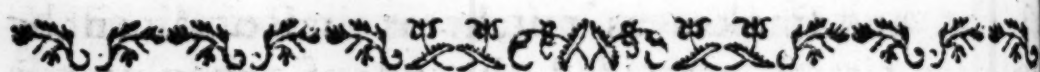
The spirit of nitre extracted by this method is as strong, and smokes as much, as that obtained by calcined vitriol, provided the oil of vitriol made use of be well concentrated; but it is generally tainted by the admixture of a small portion of the vitriolic acid, which, having no basis of its own to restrain it, is carried up by the heat before it can lay hold of the basis of the nitre.

There are several experiments in chymistry that succeed equally well whether the nitrous acid be or be not thus adulterated with a mixture of the vitriolic acid; but there are some, as we shall see, that will not succeed without a spirit of nitre so mixed. If the acid be distilled with a view to such experiments, it must be kept as it is. But most experiments require the spirit of nitre to be absolutely pure; and if it be intended for such, it must be perfectly cleansed from the vitriolic taint.

This is easily effected by mixing your spirit with very pure nitre, and distilling it a second time. The vitriolic acid, with which this spirit of nitre is adulterated, coming in contact with a great quantity

tity of undecomposed nitre, unites with its alkaline basis, and expells a proportionable quantity of the nitrous acid.

In the retort made use of to distil the nitrous acid, by means of the pure vitriolic acid, is found a *caput mortuum* differing from that left after the distillation of the same acid by the interposition of vitriol, in as much as it contains no red ferruginous earth. This is a very white saline mass, moulded in the bottom of the retort: if you pound it, dissolve it in boiling water, and evaporate the solution, it will shoot into crystals of vitriolated tartar: sometimes also it contains a portion of undecomposed nitre, which shoots after the vitriolated tartar, because it is much more soluble in water.



C H A P. III.

Of the MARINE ACID.

P R O C E S S I.

To extract Sea-Salt from Sea-Water, and from Brine-Springs. Epsom Salt.

FILTER the salt water from which you intend to extract the salt: evaporate it by boiling till you see on its surface a dark pellicle: this consists wholly of little crystals of salt just beginning to shoot: now slacken the fire, that the brine may evaporate

evaporate more slowly, and without any agitation. The crystals, which at first were very small, will become larger, and form hollow truncated pyramids, the apices whereof will point downwards, and their bases be even with the surface of the liquor.

These pyramidal crystals are only collections of small cubical crystals concreted in this form. When they have acquired a certain magnitude they fall to the bottom of the liquor. When they come to be in such heaps as almost to reach the surface of the liquor, decant it from them, and continue the evaporation till no more crystals of sea-salt will shoot.

OBSERVATIONS.

The acid of sea-salt is scarce ever found, either in sea-water or in the earth, otherwise than united with a fixed alkali of a particular kind, which is its natural basis; and consequently it is in the form of a neutral salt. This salt is plentifully dissolved in the waters of the ocean, and when obtained therefrom bears the name of *sea-salt*. It is also found in the earth in vast crystalline masses, and is then called *sal-gem*: so that sea-salt and sal-gem are but one and the same sort of salt, differing very little from each other, except as to the places where they are found.

In the earth are also found springs and fountains, whose waters are strong brines, a great deal of sea-salt being dissolved in them. These springs either rise directly from the sea, or run through some mines of sal-gem, of which they take up a quantity in their passage.

As the same, or at least nearly the same, quantity of sea-salt will continue dissolved in cold water as boiling water will take up, it cannot shoot, as nitre does, by the mere cooling of the water in which it is

is dissolved : it crystallizes only by the means of evaporation, which continually lessens the proportion of the water to the salt ; so that it is always capable of containing just so much the less sea-salt the more there is crystallized.

The brine should not boil after you perceive the pellicle of little crystals beginning to form on its surface ; for the calmness of the liquor allows them to form more regularly, and become larger. Nor after this should the evaporation be hurried on too fast ; for a saline crust would form on the liquor, which, by preventing the vapours from being carried off, would obstruct the crystallization.

If the evaporation be continued after the liquor ceases to yield any crystals of sea-salt, other crystals will be obtained of an oblong four-sided form, which have a bitter taste, and are almost always moist. This sort of salt is known by the name of *Epsom salt*, which it owes to a salt spring in England, from the water of which it was first extracted. This salt, or rather saline compound, is a congeries of Glauber's salt and sea-salt, in a manner confounded together, and mixed with some of the mother of sea-salt, in which is contained a kind of bituminous matter. These two neutral salts, which constitute the *Epsom salt*, may be easily separated from each other, by means of crystallization only. *Epsom salt* is purgative and bitter ; and therefore named *Sal Catharticum amarum*, or bitter purging salts.

There are different methods used in great works for obtaining sea-salt out of water in which it is dissolved. The simplest and easiest is that practised in France, and in all those countries which are not colder. On the sea-shore they lay out a sort of broad shallow pits, pans. or rather ponds, which the sea fills with the tide of flood. When the ponds are thus filled, they stop their communication with the sea, and leave the water to evaporate by the

heat

heat of the sun; by which means all the salt contained in it necessarily crystallizes. These pits are called *Salt ponds*. Salt can be made in this way in the summer-time only; at least in France, and other countries of the same temperature: for during the winter, when the sun has less power and rains are frequent, this method is not practicable.

For this reason, as it often rains in the province of Normandy, the inhabitants take another way to extract salt from sea-water. The labourers employed for this purpose raise heaps of sand on the shore, so that the tide waters and drenches them when it flows, and leaves the sand dry when it ebbs. During the interval between two tides of flood the sun and the air easily carry off the moisture that was left, and so the sand remains impregnated with all the salt that was contained in the evaporated water. Thus they let it acquire as much salt as it can by several returns of flood, and then wash it out with fresh water, which they evaporate over a fire in leaden boilers.

To obtain the salt from brine-springs, the water need only be evaporated: but as several of these springs contain too little salt to pay the charges that would be incurred, if the evaporation were effected by the force of fire only, the manufacturers have fallen upon a less expensive method of getting rid of the greatest part of the water, and preparing the brine for crystallization, in much less time, and with much less fire, than would otherwise have been necessary.

The method consists in making the water fall from a certain height on a great many small spars of wood, which divide it into particles like rain. This is performed under sheds open to all the winds, which pass freely through this artificial shower. By this means the water presents to the air a great extent of surface, being indeed reduced almost entirely to surface, and the evaporation is carried on with

with great ease and expedition. The water is raised by pumps to the height from which it is intended to fall *.

PROCESS II.

Experiments concerning the decomposition of sea-salt, by means of the phlogiston. Kunckel's Phosphorus.

“ **O**F pure urine that has fermented five or six
 “ days take a quantity in proportion to the
 “ quantity of phosphorus you intend to make : it
 “ requires about one third part of a hoghead to
 “ make a dram of phosphorus. Evaporate it in
 “ iron pans, till it become clotted, hard, black,
 “ and nearly like chimney-foot ; at which time it
 “ will be reduced to about a sixtieth part of its o-
 “ riginal weight before evaporation.

“ When the urine is brought to this condition
 “ put it in several portions into so many iron pots,
 “ under which you must keep a pretty brisk fire
 “ so as to make their bottoms red, and stir it in-
 “ cessantly till the volatile salt and the fetid oil be
 “ almost wholly dissipated, till the matter cease to
 “ emit any smoke, and till it smell like peach-blos-
 “ soms. Then put out the fire, and pour on the
 “ matter, which will now be reduced to a powder,
 “ somewhat more than twice its weight of warm
 “ water. Stir it about in this water, and leave it
 “ to soak therein for twenty four hours. Pour

* The Marquis de Montalembert, in a memoir read before the academy of Sciences, proposes a new method of effecting these evaporation, together with some considerable improvements in the structure and disposition of the buildings necessary for that purpose. They are called by the French *Batiments de Graduation* ; which may properly enough be rendered *Brinehouses*.

“ off the water by inclination; dry the drenched
 “ matter, and pulverize it. The previous calcina-
 “ tion carries off from the matter about a third
 “ of its weight, and the lixiviation washes out half
 “ the remainder,

“ With what remains thus calcined, washed,
 “ and dried, mix half its weight of gravel, or yel-
 “ low freestone rasped, having sifted out and
 “ thrown away all the finest particles. River-sand
 “ is not proper on this occasion, because it flies in
 “ a hot-fire. Then add to this mixture a sixteenth
 “ part of its weight of charcoal, made of beech,
 “ or of any other wood except oak, because that
 “ also flies. Moisten the whole with as much wa-
 “ ter as will bring it to a stiff paste, by working
 “ and kneading it with your hands: now intro-
 “ duce it into your retort, taking care not to daub
 “ its neck. The retort must be of the best earth,
 “ and of such a size, that when your matter is in
 “ it, a full third thereof shall still be empty.

“ Place your retort, thus charged, in a reverbe-
 “ rating furnace, so proportioned, that there may
 “ be an interval of two inches all round between
 “ the sides of the furnace and the bowl of the re-
 “ tort, even where it contracts to form the neck,
 “ which should stand inclined at an angle of sixty
 “ degrees. Stop all the apertures of the furnace,
 “ except the doors of the fire-place and ash-hole.

“ Fit on to the retort a large glass ballon two thirds
 “ full of water, and lute them together, as in
 “ distilling the smoaking spirit of nitre. In the
 “ hinder part of this ballon, a little above the sur-
 “ face of the water, a small hole must be bored.
 “ This hole is to be stopped with a small peg of
 “ birch-wood, which must slip in and out very
 “ easily, and have a small knob to prevent its fall-
 “ ing into the ballon. This peg is to be pulled out
 “ from time to time, that by applying the hand to
 “ the hole it may be known whether the air, ra-

“refied by the heat of the retort, issues out with
“too much or too little force.

“If the air rushes out with too much rapidity,
“and with a hissing noise, the door of the ash-hole
“must be entirely shut, in order to slacken the
“fire. If it do not strike pretty smartly against the
“hand, that door must be opened wider, and large
“coals thrown into the fire-place to quicken the
“fire immediately.

“The operation usually lasts four and twenty
“hours; and the following signs shew that it will
“succeed, provided the retort resist the fire.

“You must begin the operation with putting
“some unlighted charcoal in the ash-hole, and a
“little lighted charcoal at the door thereof, in or-
“der to warm the retort very slowly. When the
“whole is kindled, push it into the ash-hole, and
“close the door thereof with a tile. This moderate
“heat brings over the phlegm of the mixture. The
“same degree of fire must be kept up four hours,
“after which some coals may be laid on the grate
“of the fire-place, which the fire underneath will
“kindle by degrees. With this second heat
“brought nearer the retort, the ballon grows
“warm, and is filled with white vapours, which
“have the smell of fetid oil. In four hours after,
“this vessel will grow cool and clear; and then
“you must open the door of the ash-hole one inch,
“throw fresh coals into the fire-place every three
“minutes, and every time shut the door of it, lest
“the cold air from without should strike against
“the bottom of the retort and crack it.

“When the fire has been kept up to this degree
“for about two hours, the inside of the ballon be-
“gins to be netted over with a volatile salt of a
“singular nature, which cannot be driven up but
“by a very violent fire, and which smells pretty
“strong of peach-kernels. Care must be taken
“that this concrete salt do not stop the little hole
“in

“ in the ballon : for in that case it would burst, the
“ retort being then red-hot, and the air exceeding-
“ ly rarefied. The water in the ballon, being heat-
“ ed by the vicinity of the furnace, exhales va-
“ pours which dissolve this sprigged salt, and the
“ ballon clears up in half an hour after it has cea-
“ sed rising.

“ In about three hours from the first appearance
“ of this salt, the ballon is again filled with new
“ vapours, which smell like sal ammoniac thrown
“ upon burning coals. They condense on the sides
“ of the receiver into a salt which is not branched
“ like the former, but appears in long perpendi-
“ cular streaks, which the vapours of the water do
“ not dissolve. These white vapours are the fore-
“ runners of the phosphorus, and a little before
“ they cease to rise they lose their first smell of sal
“ ammoniac, and acquire the odour of garlick.

“ As they ascend with great rapidity, the little
“ hole must be frequently opened, to observe whe-
“ ther the hissing be not too strong : for in that
“ case it would be necessary to shut the door of the
“ ash-hole quite close. These white vapours con-
“ tinue two hours. When you find they cease ri-
“ sing, make a small passage through the dome,
“ by opening some of its registers, that the flame
“ may just begin to draw. Keep up the fire in
“ this mean state till the first volatile phosphorus
“ begin to appear.

“ This appears in about three hours after the
“ white vapours first begin to rise. In order to
“ discover it, pull out the little birchen peg once
“ every minute, and rub it against some hot part
“ of the furnace, where it will leave a trail of
“ light, if there be any phosphorus upon it.

“ Soon after you observe this sign, there will
“ issue out through the little hole of the ballon a
“ stream of blueish light, which continues of a
“ greater or shorter extent to the end of the ope-

" ration. This stream or spout of light does not
 " burn. If you hold your finger against it for
 " twenty or thirty seconds, the light will adhere to
 " it; and if you rub that finger over your hand,
 " the light will besmear it, and render it lumi-
 " nous.

" But from time to time this streamer darts out
 " the length of seven or eight inches, snapping
 " and emitting sparks of fire, and then it burns
 " all combustible bodies that come in its way.
 " When you observe this, you must manage the
 " fire very warily, and shut the door of the ash-
 " hole quite close, yet without ceasing to throw
 " coals into the fire-place every two minutes.

" The volatile phosphorus continues two hours;
 " after which the little spout of light contracts to
 " the length of a line or two: and now is the time
 " for pushing your fire to the utmost: immediate-
 " ly set the door of the ash-hole wide open, throw
 " billets of wood into it, unstop all the registers of
 " the reverberatory, supply the fire-place with
 " large coals every minute: in short, for six or se-
 " ven hours all the inside of the furnace must be
 " kept of a white heat, so that the retort shall not
 " be distinguishable.

" In this fierce extremity of heat the true phos-
 " phorus distills like an oil, or like melted wax:
 " one part thereof floats on the water in the reci-
 " pient, the other falls to the bottom. At last
 " the operation is known to be quite over when
 " the upper part of the ballon, in which the vola-
 " tile phosphorus appears condensed in a blackish
 " film begins to grow red; for this shews that the
 " phosphorus is burnt where the red spot appears.
 " You must now stop all the registers, and shut all
 " the doors of the furnace, in order to smother
 " the fire; and then close up the little hole in the
 " ballon with fat lute or bees-wax. In this condi-
 " tion the whole must be left for two days; be-
 " cause

" cause the vessels must not be separated till they
 " are perfectly cold, lest the phosphorus should
 " take fire.

" As soon as the fire is out, the ballon, which
 " is then in the dark, presents a most agreeable ob-
 " ject: all the empty part thereof above the water
 " seems filled with a beautiful blue light; which
 " continues for seven or eight hours, or as long as
 " the ballon keeps warm, never disappearing till it
 " is cooled.

" When the furnace is quite cold take out the
 " vessels, and separate them from each other as
 " neatly as possible. With a linen cloth wipe away
 " all the black stuff you find in the mouth of the
 " ballon; for if that filth should mix with the
 " phosphorus, it would hinder it from being
 " transparent when moulded. This must be done
 " with great expedition: after which pour into the
 " ballon two or three quarts of cold water, to ac-
 " celerate the precipitation of the phosphorus that
 " swims at top. Then agitate the water in the
 " ballon, to rinse out all the phosphorus that may
 " stick to the sides; pour out all the water thus
 " shaken and turbid, into a very clean earthen
 " pan, and let it stand till it grows clear. Then
 " decant this first useless water, and on the black-
 " ish sediment, left at the bottom of the pan, pour
 " some boiling water to melt the phosphorus;
 " which thereupon unites with the fuliginous mat-
 " ter, or volatile phosphorus, that precipitated
 " with it, both together forming a mass of the co-
 " lour of slate. When this water, in which you
 " have melted the phosphorus, is cool enough,
 " take out the phosphorus, throw it into cold wa-
 " ter, and therein break it into little bits in order
 " to mould it.

" Then take a matrass, having a long neck
 " somewhat wider next the body than at its
 " mouth: cut off half the body, so as to make a
 " funnel

" funnel of the neck-part, the smaller end of
 " which must be stopped with a cork. The first
 " mould being thus prepared, plunge it endwise,
 " with its mouth uppermost, in a vessel full of
 " boiling water, and fill it with that water. Into
 " this funnel throw the little bits of your slate-like
 " mass, which will melt again in this hot water,
 " and fall so melted to the bottom of the tube.
 " Stir this melted matter with an iron wire, to
 " promote the separation of the phosphorus from
 " the fuliginous matter with which it is fouled,
 " and which, being less ponderous than the phos-
 " phorus, will gradually rise above it towards the
 " upper part of the cylinder.
 " Keep the water in the vessel as hot as at first,
 " till on taking out the tube you see the phospho-
 " rus clean and transparent. Let the clear tube
 " cool a little, and then set it in cold water, where
 " the phosphorus will congeal as it cools. When
 " it is perfectly congealed, pull out the cork, and
 " with a small rod, near as big as the tube, push
 " the cylinder of phosphorus towards the mouth
 " of the funnel, where the feculency lies. Cut
 " off the black part of the cylinder, and keep it
 " apart : For when you have got a quantity there-
 " of, you may melt it over again in the same man-
 " ner, and separate the clean phosphorus, which it
 " still contains. As to the rest of the cylinder,
 " which is clean and transparent, if you intend to
 " mould it into smaller cylinders, you may cut it
 " in slices, and melt it again by the help of boiling
 " water in glass tubes of smaller dimensions."

OBSERVATIONS.

This process for making phosphorus is copied
 from the Memoirs of the Academy of Sciences for
 the year 1737 ; where it is described by M. Hellot,
 with so much accuracy, clearness, and precision,

that

that I thought I could not do better than transcribe it, without departing from the author's own expressions, for the sake of such as may not have those memoirs. We shall take occasion, in these observations, to point out some essential circumstances which I have omitted in the description of the process, that I might not break the connection between the phenomena that happen in the course of this experiment.

It is proper to observe, in the first place, that one of the most usual causes of miscarriage in this operation is a defect of the requisite qualities in the retort employed. It is absolutely necessary to have that vessel made of the best earth, and so well made that it shall be capable of resisting the utmost violence of fire, continued for a very long time; as appears by the description of the process. The retorts commonly sold by potters, and other earthenware men, are not fit for this operation; and Mr. Hellot was obliged to send to Hesse-Cassel for such as he wanted.

We shall in the second place, observe with M. Hellot that, "before you set your retort in the furnace, it is proper to make an essay of your matter, to see if there be reason to hope for success. For this purpose put about an ounce thereof into a small crucible, and heat it till the vessel be red. The mixture, after having smoked, ought to chop or crack without puffing up, or even rising in the least. From these cracks will issue undulating flames, white and blueish, darting upwards with rapidity. This is the first volatile phosphorus, which occasions all the danger of the operation. When these first flashes are over, increase the heat of your matter by laying a large live coal upon the crucible. You will then see the second phosphorus, like a luminous, steady vapour, of a colour inclining to violet, covering the whole surface of the matter; it continues

“ tinues for a very long time, and diffuses a smell
 “ of garlick, which is the distinguishing odour of
 “ the phosphorus you are seeking.

“ When this luminous vapour is entirely gone,
 “ pour the red hot matter out of the crucible upon
 “ an iron plate. If you do not find one drop of salt
 “ in fusion, but that, on the contrary, the whole
 “ falls readily into powder, 'tis a proof that your
 “ matter was sufficiently lixiviated, and that it
 “ contains no more fixed salt, or sea-salt, if you
 “ will, than is requisite. If you find on the plate
 “ a drop of salt coagulated, it shews that there is
 “ too much left in, and that there is danger of
 “ your miscarrying in the operation; because the
 “ redundant salt would corrode, and eat through
 “ the retort. In this case your matter must be
 “ washed again, and then sufficiently dried.”

Our third observation shall be concerning the furnace proper to be employed in this operation. This furnace must be so constructed, that within a narrow compass it may give a heat at least equal to that of a glass-house furnace, or rather greater, especially during the last seven or eight hours of the operation. M. Hellot in his memoir gives an exact description of such a furnace.

“ As certain accidents may happen in the course
 “ of the operation, some precautions are to be taken
 “ against them. For instance, if the ballon should
 “ break while the phosphorus is distilling, and any
 “ of it should fall on combustible bodies, it would
 “ set them on fire, and probably burn the laboratory, because it is not to be extinguished
 “ without the greatest difficulty. The furnace
 “ must therefore be erected under some vault, or
 “ upon a bed of brick-work raised under some
 “ chimney that draws well: nor must any furniture or utensil of wood be left near it. If a little
 “ the flaming phosphorus should fall on a man's
 “ legs or hands, in less than three minutes it would
 “ burn

“ burn its way to the very bone. In such a case
 “ nothing but urine will stop its progress.

“ If the retort crack while the phosphorus is
 “ distilling, there is an unsuccessful end of your
 “ operation. It is easy to perceive this by the stink
 “ of garlick which you will smell about the fur-
 “ nace ; and moreover, the flame that issues thro’
 “ the apertures of the reverberatory will be of a
 “ beautiful violet colour. The acid of sea-salt al-
 “ ways gives this colour to the flame of such mat-
 “ ters as are burnt along with it. But if the re-
 “ tort break before the phosphorus hath made its
 “ appearance, its contents may be saved by throw-
 “ ing a number of cold bricks into the fire-place,
 “ and upon them a little water to quench the fire
 “ at once.” All these useful observations we owe
 also to M. Hellot.

The phosphorus here described was first discover-
 ed by a citizen of Hamburgh named Brandt, who
 worked upon urine in search of the philosopher’s
 stone. Afterwards two other skilful chymists, who
 knew nothing more of the process than that phos-
 phorus was obtained from urine, or in general
 from the human body, likewise endeavoured to
 discover it ; and each of them separately did actual-
 ly make the discovery. These two chymists were
 Kunckel and Boyle.

The former perfected the discovery, and found
 out a method of making it in considerable quantities
 at a time ; which occasioned it to be called *Kunckel’s*
phosphorus. The other, who was an English gentle-
 man, had not time to bring his discovery to per-
 fection, and contented himself with lodging a vou-
 cher of his having discovered it in the hands of the
 Secretary of the Royal Society of London, who
 gave him a certificate thereof.

“ Though Brandt, says M. Hellot, who had be-
 “ fore this sold his secret to a chymist named
 “ Krafft, sold it afterwards to several other per-
 “ sons,

“ sons, and even at a very low rate ; and though
 “ Mr. Boyle published the process for making it ;
 “ yet it is extremely probable that both of them
 “ kept in their own hands the master-key : I mean
 “ *the particur management necessary to make the*
 “ *operation succeed* ; for till Kunckel found it out,
 “ no other chymist ever made any considerable
 “ quantity thereof, except Mr. Godfrey Hankwitz,
 “ an English chymist, to whom Mr. Boyle revealed
 “ the whole mystery.

“ Nevertheless, continues he, we are very far
 “ from alledging that all those who have described
 “ this operation meant to impose upon the world ;
 “ but we conceive that most of them having ob-
 “ served luminous vapours in the ballon, and some
 “ sparks about the juncture of the vessels, were
 “ contented with those appearances. And thus it
 “ came to pass, that, after Kunckel and Boyle
 “ died, Mr. Godfrey Hankwitz was the only chy-
 “ mist that could supply Europe therewith ; on
 “ which account it is likewise very well known by
 “ the name of *English phosphorus*.”

Almost all the chymists consider phosphorus as a
 substance consisting of the acid of sea-salt combin-
 ed with the phlogiston, in the same manner as sul-
 phur consists of the vitriolic acid combined with
 the phlogiston. This opinion is founded on the
 following principles.

First, urine abounds with sea-salt, and contains
 also a great deal of phlogiston : now these are the
 ingredients of which they conjecture phosphorus to
 be composed,

Secondly, phosphorus has many of the proper-
 ties of sulphur ; such as being soluble in oils ; melt-
 ing with a gentle heat ; being very combustible ;
 burning without any foot ; giving a vivid and blue-
 ish flame ; and lastly, leaving an acid liquor when
 burnt : sensible proofs that it differs from sulphur
 in nothing but the nature of its acid.

Thirdly,

Thirdly, this acid of phosphorus, being mixed with a solution of silver in spirit of nitre, precipitates the silver, and this precipitate is a true *luna cornea*, which appears to be more volatile even than the common sort; as M. Hellot tells us, who made the experiment. This fact proves incontestably that the acid of phosphorus is of the same nature with that of sea-salt: for all chymists know that the property of precipitating silver in a *luna cornea* belongs to the marine acid only.

Fourthly, M. Stahl observes that, if sea-salt be cast on live-coals, they instantly burn with great activity; then they emit a very vivid flame, and are much sooner consumed than if none of this salt had touched them; that sea-salt in substance, which will bear the violence of fire a considerable time when fused in a crucible, without sustaining any sensible diminution, yet evaporates very quickly, and is reduced to white flowers, by the immediate contact of burning coals; and lastly, that the flame which rises on this occasion is of a blue colour inclining to violet, especially if it be not thrown directly on the coals themselves, but kept in fusion amidst burning coals, in a crucible so placed that the vapour of the salt may join with the enflamed phlogiston as it rises from the coals.

These experiments of Mr. Stahl prove that the phlogiston acts upon the acid of sea-salt, even while it is combined with its alkaline basis. The flame that appears on this occasion may be considered as an imperfect phosphorus: and indeed its colour is exactly like that of phosphorus.

All the facts above related evince that the acid of phosphorus is akin to that of sea-salt; or rather that it is the very same. But there are other facts which prove that this acid undergoes some change, at least, some peculiar preparation, before it enters into the composition of a true phosphorus, and that, when extricated therefrom by burning, it is not

not a pure acid of sea-salt, but is still adulterated with a mixture of some other substance, which makes it considerably different from that acid. For these observations we are obliged to M. Marggraff, of the Academy of Sciences at Berlin, a celebrated chymist. I shall presently give an account of his principal experiments as succinctly as possible.

M. Marggraff hath also published a process for making phosphorus, and assures us that by means thereof we may obtain in less time, with less heat, less trouble, and less expence, a greater quantity of phosphorus than by any other method. His operation is this :

He takes two pounds of sal ammoniac in powder, which he mixes accurately with four pounds of minium. This mixture he puts into a glass retort, and with a graduated fire draws off a very sharp, volatile, urinous spirit.

We observed in our theoretical elements that some metallic substances have the property of decomposing sal ammoniac, and separating its volatile alkali; concerning which phenomenon we there gave our opinion. Minium, which is a calx of lead, is one of those metallic substances. In this experiment it decomposes the sal ammoniac, and separates its volatile alkali; what remains in the retort is a combination of the minium with the acid of the sal ammoniac, which is well known to be the same with the marine acid; and consequently the residue of this operation is a sort of *Plumbum corneum*.

The quantity thereof is four pounds eight ounces. Of this he mixes three pounds with nine or ten pounds of urine, that has stood putrefying for two months, evaporated to the consistence of honey. These he mixes by little and little in an iron pan over the fire, stirring the mixture from time to time. Then he adds half a pound of charcoal dust,

and evaporates the matter, kept continually stirring, till the whole be brought to a black powder. He next distills the mixture in a glass retort with degrees of fire, which he raises towards the end so as to make the retort red-hot, in order to expell all the urinous spirit, superfluous oil, and ammoniacal salt. The distillation being finished, there remains nothing in the retort but a very friable *caput mortuum*.

This remainder he pulverises again, and throws a pinch thereof on live-coals, thereby to discover whether or no the matter be rightly prepared, and in order, for yielding phosphorus. If it be so, it presently emits an arsenical odour, and a blue undulating flame, which passes over the surface of the coals like a wave.

Being thus assured of the success of his operation he puts one half of his matter, in three equal parts, into three small earthen German retorts, capable of holding about eighteen ounces of water a-piece. These three retorts, none of which is above three quarters full, he places together in one reverberatory furnace, built much like those we have described, except that it is so constructed as to hold the three retorts disposed in one line. To each retort he lutes a recipient something more than half full of water, ordering the whole in such a manner, that the noses of his retorts almost touch the surface of the water.

He begins the distillation with warming the retorts slowly, for about an hour, by a gentle heat. When that time is elapsed he raises the fire gradually, so that in half an hour more the coals begin to touch the bottoms of the retorts. He continues throwing coals into the furnace by little and little, till they rise half way the height of the retorts; and in this he employs another half hour. Lastly, in the next half hour he raises the coals above the bowls of the retorts.

Then the phosphorus begins to ascend in clouds : on this he instantly increases the heat of the fire as much as possible, filling the furnace quite up with coals, and making the retorts very red. This degree of fire causes the phosphorus to distill in drops which fall to the bottom of the water. He keeps up this intense heat for an hour and half, at the end of which the operation is finished ; so that it lasts but four hours and a half in all : nay, he further assures us that an artist, well versed in managing the fire, may perform it in four hours only. In the same manner he distills the second moiety of his mixture in three other such retorts.

The advantage he finds in making use of several small retorts, instead of a single large one, is that the heat penetrates them with more ease, and the operation is performed with less fire, and in less time. He purifies and moulds his phosphorus much in the same manner as M. Hellot does. From the quantity of ingredients above mentioned, he obtains two ounces and a half of fine crystalline moulded phosphorus.

M. Marggraff considering, as a consequence of the experiments above related, that a highly concentrated acid of sea-salt contributes greatly toward the formation of phosphorus, proceeded to try several other experiments, in which he employed the acid in a state of combination with other bases. He mixed, for instance, an ounce of *luna cornea* with an ounce and half of putrefied and inspissated urine, and from the mixture obtained a very beautiful phosphorus.

In short, the several experiments mentioned having thoroughly persuaded him that the acid of sea-salt, provided it were highly concentrated, would combine with the phlogiston as readily as the vitriolic acid does, he resolved to try whether he could not make phosphorus with matters containing the acid

acid and the phlogiston, without making use of any urine.

With this view he made a great number of different trials, wherein he employed sea-salt in substance, sal ammoniac, plumbum corneum, luna cornea, fixed sal ammoniac, otherwise called *Oil of lime*. These several substances, all of which contain the acid of sea-salt, he mixed with sundry matters abounding in phlogiston, different vegetable coals, and even animal matters, such as the oil of hartshorn, human blood, &c. varying the proportions of these substances many different ways, without ever being able to produce a single atom of phosphorus: which gave this able chymist just cause to suspect that the marine acid, while pure and crude, is not capable of combining with the phlogiston in the manner requisite to form a phosphorus; that for this purpose it is necessary the acid should have contracted a previous union with some other matter; and that the acid found in urine hath probably undergone the necessary change. M. Marggraff is of opinion that the matter, which by its union renders the marine acid capable of entering into the composition of phosphorus, is a sort of exceedingly subtile vitrifiable earth. The experiments he made upon the acid of phosphorus will shew that his notion is not altogether groundless. M. Marggraff having let some urine, evaporated to the consistence of honey, stand quiet in a cool place, obtained from it, by crystallization, a salt of a singular nature. By distilling this urine afterwards, he satisfied himself that it yielded him much less phosphorus than urine from which no salt had been extracted; and as it cannot be entirely deprived of this salt, he thinks that the small quantity of phosphorus, which this urine yielded him, came from the salt that was still left in it.

Further, he distilled this salt separately with lamp black, and obtained from it a considerable quantity

of very fine phosphorus. He even mixed *luna cornea* with this salt, in order to see whether it would not increase the quantity of his phosphorus; but without success: whence he concluded that in this saline matter resides the true acid that is fit to enter into the composition of phosphorus. This opinion is confirmed by several experiments on the acid of phosphorus, which he found to have some properties resembling those of this salt.

The acid of phosphorus seems to be more fixed than any other: and therefore if you would separate it, by burning, from the phlogiston with which it is united, there is no occasion for such an apparatus of vessels as is employed for obtaining the spirit of sulphur. For this acid will remain at the bottom of the vessel in which you burn your phosphorus: indeed, if it be urged by the force of fire, its most subtile part evaporates, and the remainder appears in the form of a vitrified matter.

This acid effervesces with fixed and volatile alkalis, and therewith forms neutral salts; but very different from sea-salt, and from sal ammoniac. That which has a fixed alkali for its basis does not crackle when thrown on burning coals; but swells and vitrifies like borax. That which has a volatile alkali for its basis shoots into long pointed crystals, and, being urged by fire in a retort, lets go its volatile alkali, a vitrified matter remaining behind. This salt is like that abovementioned, as obtained from urine and yielding phosphorus.

It appears from the experiments adduced, that the acid of phosphorus tends always to vitrification, which proves that it is not pure, and gave M. Marggraff cause to think that it is altered by the admixture of a very subtile vitrifiable earth.

M. Marggraff also obtained phosphorus from several vegetable substances which we use every day for food. This gives him occasion to conjecture that the salt requisite to the formation of phosphorus

rus exists in vegetables, and passes from thence into the animals that feed upon them.

Lastly, he concludes his dissertation by informing us of a very important truth, viz. That the acid obtained from phosphorus, by burning it, will serve to form phosphorus anew; for which purpose it need only be combined with some charred coal, such as lamp-black, and distilled.

From what hath been said on this subject, it is plain the chymists have a great many curious and interesting enquiries to make concerning phosphorus, and particularly concerning its acid.

I shall conclude this article with an account of certain properties of phosphorus which I have not yet mentioned.

Phosphorus dissolves by lying exposed to the air. What water cannot effect, says M. Hellot, or at least requires eight or ten years to bring about, the moisture of the air accomplishes in ten or twelve days; whether it be that the phosphorus takes fire in the air, and the inflammable part evaporating, almost entirely, leaves the acid of the phosphorus naked, which, like all other acids, when exceedingly concentrated, is very greedy of moisture; or else that the moisture of the air, being water divided into infinitely fine particles, is so subtile as to find its way through the pores of the phosphorus, into which the grosser particles of common water can by no means insinuate themselves.

Phosphorus heated by the vicinity of fire, or by being any way rubbed, soon takes fire and burns fiercely. It is soluble in all oils and in æther, giving to those liquors the property of appearing luminous when the bottle containing the solution is opened. Being boiled in water, it likewise communicates thereto this luminous quality. M. Morin, professor at Chartres, is the author of this observation.

The late Mr. Grosse, a celebrated chymist of the Academy of Sciences, observed that phosphorus being dissolved in essential oils crystallizes therein. These crystals take fire in the air, either when thrown into a dry vessel, or wrapt up in a piece of paper. If they be dipped in spirit of wine, and taken out immediately, they do not afterwards take fire in the air: they smoke a little, and for a very short time, but hardly waste at all. Though some of them were left in a spoon for a fortnight, they did not seem to have lost any thing of their bulk: but, when the spoon was warmed a little, they took fire, just like common phosphorus that had never been dissolved and crystallized in an essential oil.

M. Marggraff, having put a dram of phosphorus with an ounce of highly concentrated spirit of nitre into a glass retort, observed that, without the help of fire, the acid dissolved the phosphorus; that part of the acid came over into the recipient which was luted to the retort; that at the same time the phosphorus took fire, burnt furiously, and burst the vessels with explosion. Nothing of this kind happens when any of the other acids, though concentrated, are applied to phosphorus.

P R O C E S S III.

To decompose Sea-salt by means of the Vitriolic Acid. Glauber's Salt. The Purification and Concentration of Spirit of Salt.

PUT the sea-salt from which you mean to extract the acid into an unglazed earthen pipkin, and set it amidst live coals. The salt will decrepi-
tate,

rate, grow dry, and fall into a powder. Put this decrepitated salt into a tubulated glass retort, leaving two thirds thereof empty. Set the retort in a reverberating furnace; apply a receiver like that used in distilling the smoking spirit of nitre, and lute it on in the same manner, or rather more exactly if possible. Then through the hole, in the upper convexity of the retort, pour a quantity of highly concentrated oil of vitriol, equal in weight to about a third part of your salt, and immediately shut the hole very close with a glass stopple, first ground therein with emery so as to fit it exactly.

As soon as the oil of vitriol touches the salt, the retort and receiver will be filled with abundance of white vapours; and soon after, without lighting any fire in the furnace, drops of a yellow liquor will distil from the nose of the retort. Let the distillation proceed in this manner without fire, as long as you perceive any drops come: afterwards kindle a very small fire under the retort, and continue distilling and raising the fire by very slow degrees, and with great caution, to the end of the distillation; which will be finished before you have occasion to make the retort red-hot. Unlute the vessels, and without delay pour the liquor, which is a very smoking spirit of salt, out of the receiver into a crystal bottle, like that directed for the smoking spirit of nitre.

OBSERVATIONS.

Sea-salt, as hath been already said, is a neutral salt composed of an acid, which differs from those of vitriol and nitre, combined with a fixed alkali that has some peculiar properties; but does not vary from the others in its affinities. This salt therefore, as well as nitre, must be decomposed by the vitriolic acid; which accordingly is the case in the process

process here described. The vitriolic acid unites with the alkaline basis of the sea-salt, and separates its acid; and that with much greater facility than it expels the nitrous acid from its alkaline basis, because the acid of sea-salt has not so great an affinity as the nitrous acid with fixed alkalis.

As a highly concentrated oil of vitriol is used on this occasion, and as the sea-salt is previously dried and decrepitated, the acid obtained from it by distillation is very free from phlegm, and always smokes, even more violently than the strongest acid of nitre. The vapours of this acid are also much more elastic and more penetrating than those of the nitrous acid: on which account this distillation of the smoking spirit of salt is one of the most difficult, most laborious, and most dangerous operations in chymistry.

This process requires, a tubulated retort, that the oil of vitriol may be mixed with the sea-salt after the receiver is well luted to the retort, and not before: for, as soon as these two matters come together, the spirit of salt rushes out with so much impetuosity, that, if the vessels were not luted at the time, the copious vapours that would issue through the neck of the ballon would so moisten it, as well as the neck of the retort, that it would be impracticable to apply the lute and secure the joint as the operation requires. Moreover, the operator would be exposed to those dangerous fumes, which, on this occasion, rush out and enter the lungs, with such incredible activity as to threaten instant suffocation.

Having said so much of the elasticity and activity of the fumes of spirit of salt, it is needless to insist upon the necessity of giving vent to the vessels from time to time, by opening the little hole of the ballon: indeed the best way to prevent the loss of a great many vapours, on this occasion, is to employ adopters, and cover them with wet canvas, which

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which will cool and condense the vapours they contain.

When the operation is finished, we find a white, saline mass at the bottom of the retort as in a mould. If this mass be dissolved in water, and the solution crystallized, it yield a considerable quantity of sea-salt that hath not been decomposed, and a neutral salt consisting of the vitriolic acid united with the alkaline basis of that part which hath been decomposed. This neutral salt, which bears the name of *Glauber* its inventor, differs from vitriolated tartar, or the *sal de duobus*, which remains after distilling the nitrous acid, especially in that it is more fusible, more soluble in water, and hath its crystals differently figured. But as in these two salts the acid is the same, the differences that appear between them must be attributed to the peculiar nature of the basis of sea-salt.

Spirit of salt drawn by the process above described is tainted with a small mixture of the vitriolic acid, carried up by the force of fire before it had time to combine with the alkali of the sea-salt; which happens likewise to the nitrous acid procured in the same manner. If you desire to have it pure, and absolutely free from the acid of vitriol, it must be distilled a second time from sea-salt, as the acid of nitre was before directed to be distilled again from fresh nitre, in order to purify it from any vitriolic taint.

Sea-salt, as well as nitre, may be decomposed by any combination of the vitriolic acid with a metallic or earthy substance: but it is proper to observe, that if you distil spirit of salt by means of green vitriol, the operation will not succeed so well as when spirit of nitre is distilled in the same manner: less spirit is obtained, and a much fiercer fire is required.

The cause of this lies in the property which the acid of sea-salt possesses of dissolving iron, even when

when deprived of a part of its phlogiston by having contracted an union with another acid; so that it is no sooner dislodged from its own basis by the vitriolic acid, than it unites with the ferruginous basis of the vitriol, from which it cannot be separated but by a most violent fire. This is the consequence more especially when calcined vitriol is made use of: for moisture, as we shall presently see, greatly facilitates the separation of the marine acid from those substances with which it is united.

When you do not desire a highly dephlegmated and smoking spirit of salt, you may distil with the additament of any earth containing the vitriolic acid; as clay, for instance, or bole. To this end, one part of sea-salt, slightly dried and reduced to a fine powder, must be accurately mingled with two parts of the earth you intend to employ likewise pulverized; of this mixture make a stiff paste with a proper quantity of rain water, and having formed little balls thereof, about the size of a hazel nut, let them dry in the sun; when dry put them into a stone or coated glass retort, leaving a third part thereof empty; set this vessel in a reverberating furnace, covered with its dome; apply a receiver, which need not be luted on for some time; and heat the vessels very slowly. At first an insipid water will rise; which must be thrown away: afterwards the spirit of salt will appear in white clouds. Now lute your vessels, and raise the fire by degrees; which towards the end must be pushed to the utmost extremity. The operation is known to be finished when no drops fall from the nose of the retort, the receiver cools, and the white vapours that filled it are seen no more.

The spirit of salt obtained by the process here delivered does not smoke, and contains much more phlegm than that which is distilled by means of the concentrated oil of vitriol; because the earth, though

though dried in the sun, still retains a great deal of moisture, which commixes with the acid of the sea-salt. Consequently it is much easier to collect its vapours; so that this operation is attended with much less trouble than the other. Nevertheless it is adviseable to proceed gently; to apply but little heat at first, and to unstop every now and then the small hole of the receiver: for a quantity of the vapours of spirit of salt, even when weakened by the admixture of water, is very apt to burst the vessels.

A much greater degree of fire is necessary to raise the spirit of salt by this latter process, than by that in which the pure vitriolic acid is employed: for, as fast as the spirit of salt is dislodged from its own basis, by the vitriolic acid contained in the earth made use of, part of it joins that earth, and cannot be separated from it without the most violent heat.

A spirit of salt that shall not smoke may also be obtained by means of the pure vitriolic acid. Spirit of vitriol, or oil of vitriol, lowered with a good deal of water, will do the business.

Some chymists direct a little water to be placed in the receiver, when the spirit of salt is to be distilled by the intermedium of concentrated oil of vitriol, in order to make the acid vapours to condense more readily. By this means indeed some of the inconveniencies attending the distillation of smoking spirit of salt may be avoided: but on the other hand, the acid vapours being absolutely suffocated by the water as fast as they come over, the spirit of salt obtained by this method will be no less aqueous than that procured by the interposition of earths: so that here is an expence to no manner of purpose. Therefore, when a spirit of salt is desired that shall not smoke, it is best to employ an admixture of earth; and that so much the rather as the marine acid obtained by this means is purer and freer

freer from any vitriolic taint, for the reasons already assigned.

Part of the acid of sea-salt may be separated from its alkaline basis by the force of fire alone, without the intervention of any other body. With this view the salt must be put into the retort without being dried. At first an insipid water rises; but it gradually becomes acid, and hath all the properties of spirit of salt. When the salt in the retort is grown perfectly dry, nothing more can be forced over by any degree of heat whatever. If you would obtain more acid from the same salt, you must take it out of the retort, where you will find it in a lump, reduce it to powder, and expose it to the air for some time, that it may attract the moisture thereof; or else wet it at once with some rain water, and distil as before. You will again have an insipid water, and a little spirit of salt; which will in like manner cease to rise when the salt in the retort becomes dry. This operation may be repeated as often as shall be thought proper: and perhaps it may be possible to decompose sea-salt entirely by means thereof, without the interposition of any other body. The spirit of salt thus obtained is exceeding weak, in small quantity, and loaded with much water.

This experiment proves, that moisture greatly facilitates the separation of the acid of sea-salt from the matters with which it is united: and this is the reason that, in distilling spirit of salt with the aditament of an earth, the operation requires much less fire at the beginning, while the earth and salt retain a great deal of humidity, than towards the end, when they begin to grow dry.

After the operation there remains in the retort a saline and earthy mass, which contains, 1. Some entire sea-salt that has suffered no decomposition; 2. A Glauber's salt, which is, as we said before, a neutral salt consisting of the vitriolic acid united with

with the alkaline basis of the sea-salt, from which it hath expelled its proper acid; 3. Part of the earth used as an intermedium, still retaining a portion of its original vitriolic acid, which, happening not to lie near enough to any particles of sea-salt, could not exert its power in decomposing them, and so remains united with its earthy basis; 4. Another part of the same earth, impregnated with some of the marine acid, which combined therewith upon being expelled from its alkaline basis by the vitriolic acid, and which the force of fire was unable to separate from it when the matters were grown perfectly dry. In consequence of what remains in this *caput mortuum*, if the whole mass be triturated, moistened with a little water, and distilled a second time, considerably more spirit of salt will be obtained from it: and the same is to be said of all distillations of this sort.

Spirit of salt obtained by the means of any other additament than concentrated oil of vitriol is generally very weak: but it may be dephlegmated and concentrated, if required, much in the same manner as oil of vitriol. For this purpose you must put it into a glass cucurbit, set it in a *balneum marie*, fit thereto a head and a receiver, and with a moderate degree of heat draw off one third or one half of the liquor. What comes over into the receiver will be the most aqueous part, which being the lightest will rise first, impregnated however with a little acid: in the cucurbit will be left a concentrated spirit of salt, or the most acid part, which being the heaviest will not rise with the degree of heat that is capable of carrying up the phlegm. Spirit of salt thus concentrated, called also *oil of salt*, does not smoke: it is of a yellow colour inclining to green, and an agreeable smell not unlike that of saffron.

PROCESS IV.

*To decompose Sea-salt by means of the Nitrous Acid,
Aqua regis. Quadrangular Nitre.*

TAKE dried sea-salt: bruise it to powder: put it into a glass retort, leaving one half of the vessel empty. Pour upon it a third of its weight of good spirit of retort. Place your retort in the sand-bath of a reverberating furnace; put on the dome; lute to the retort a receiver having a small hole in it, and heat the vessels very slowly. There will come over into the receiver some vapours, and an acid liquor. Increase the fire gradually till nothing more rises. Then unlute the vessels, and pour the liquor out of the receiver into a crystal bottle, stopped like others containing acid spirits.

OBSERVATIONS.

The nitrous acid hath a greater affinity than the marine acid with fixed alkalis. When therefore spirit of nitre and sea-salt are mixed together, the same consequences, in some measure, will follow, as when the vitriolic acid is mixed with that salt; that is, the nitrous acid will, like the vitriolic, decompose it, by dislodging its acid from its alkaline basis, and assuming its place. But as the nitrous acid is considerably weaker, and much lighter than the vitriolic acid; a good deal of it rises along with the acid of sea-salt during the operation. The liquor found in the receiver is therefore a true *aqua regis*.

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Of BORAX.

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Reduce to a fine powder the borax from which you intend to extract the sedative falt. Put this powder into a wide-necked glafs retort. Pour
B. b 2. upon

upon it an eighth part of its weight of common water, to moisten the powder ; and then add concentrated oil of vitriol, to the weight of somewhat more than a fourth part of the weight of the borax. Set the retort in a reverberatory, make a moderate fire at first, and augment it gradually till the retort become red-hot.

A little phlegm will first come over, and then with the last moisture that the heat expels the sedative salt will rise ; by which means some of it will be dissolved in this last phlegm, and pass therewith into the receiver ; but most of it will adhere in the form of saline flowers to the fore-part of the neck of the retort, just where it is clear of the groove of the furnace. There they collect into a heap, which the succeeding flowers push insensibly forward till they slightly stop the passage. Those which rise after the neck is thus stopped stick to the after-part of it which is hot, vitrify in some measure, and form a circle of fused salt. In this state the flowers of the sedative salt seem to issue out of the circle, as from their basis : they appear like very thin, light, shining scales, and must be brushed off with a feather.

At the bottom of the retort will be left a saline mass : dissolve this in a sufficient quantity of hot water ; filter the solution in order to free it from a brown earth ; which it deposits ; set the liquor to evaporate, and crystals of sedative salt will form in it.

OBSERVATIONS.

Though borax is of great use in many chymical operations, especially in the fusion of metals, as we shall have occasion to see, yet, till of late years chymists were quite ignorant of its nature, as they still are of its origin : concerning which we know nothing

nothing with certainty, but that it comes rough from the East-Indies, and is purified by the Dutch.

M. Homberg was one of the first that attempted to analyse this salt. He shewed that on mixing it with the vitriolic acid, and distilling the mixture, a salt sublimes in little fine needles. This product of borax he called by the name of *Sedative salt*, because he found it had the property of moderating the great tumult and heat of the blood in fevers.

After M. Homberg other chymists also exercised themselves on borax. M. Lemery discovered that the vitriolic is not the only acid by means of which the sedative salt may be obtained from borax; but that either of the other two mineral acids, the nitrous or the marine, may be used in its stead.

M. Geoffroy hath greatly facilitated the means of obtaining the sedative salt from Borax; having shewn that it may be extracted by crystallization as well as by sublimation; and that the sedative salt so obtained is in no respect inferior to that which was procured before by sublimation only. To him also we are indebted for the discovery, that in the composition of borax there is an alkaline salt of the same nature as the basis of sea-salt. This he found by observing that he got a Glauber's salt from a solution of borax, into which he had poured some vitriolic acid with a view to obtain its sedative salt.

Lastly, M. Baron, whom we mentioned before on occasion of this salt, hath proved, by a great number of experiments, that a sedative salt may be procured from borax by the help of vegetable acids, which was never done by any body before him; that the sedative salt is not a combination of an alkaline matter with the acid made use of in extracting it, as some of its properties seemed to indicate; but that it exists previously and completely formed in the borax; that the acid employed to extract it only helps to disengage it from the alkali with

which it is united ; that this alkali is actually of the same nature as the basis of sea-salt, because that after extracting the sedative salt, which by its union therewith forms the borax, a neutral salt is found, of the same sort with that which would be produced by combining the basis of sea-salt with the particular acid made use of ; that is, if with the vitriolic acid, a Glauber's salt ; if, with the nitrous acid, a quadrangular nitre ; and if, with the marine acid, a true sea-salt ; and lastly, that the sedative salt may be re-united to its alkali, and reproduce a borax.

Nothing therefore now remains, to give us all the insight we can desire into the nature of borax, but to know what the sedative salt is. M. Baron hath already given us certain negative notices concerning it, by shewing what it is not ; that is, that the acid employed in its extraction doth not enter its composition. We have great reason to hope that he will carry his enquiries still further, and clear up all our doubts on this subject.

The sedative salt may be extracted from Borax, not only by the means of pure and simple acids, but also by the same acids combined with a metallic basis. Thus vitriols, for instance, may be employed for this purpose with good success. It is easy to see that the vitriol must be decomposed on this occasion, and that its acid cannot unite with the alkali in which the sedative salt is lodged, without quitting its metallic basis, which must of course precipitate.

The sedative salt actually sublimes, when a liquid containing it is distilled ; but it does not therefore follow that it is naturally volatile. It rises only by the aid of the water with which it is mixed. The proof of this assertion is, that, when all the humidity of the mixture containing this salt is dissipated, no more salt will rise, be the fire ever so violent ; and that, by adding more water to moisten the
dried

dried mafs containing it, more falt will every time be obtained, through many repeated diffillations. In the fame manner, if fome fedative falt be moistened, and expofed to a proper degree of heat, a fmall quantity thereof will rife at firft by the help of the water ; but, as foon as it grows dry it remains exceedingly fixed. This obfervation we owe to M. Rouelle.

The fedative falt hath the appearance and the tafte of a neutral falt: it does not change the colour of the juice of violets : nor does it eafily diffolve in water ; for it requires a quart of boiling water to diffolve two ounces of it : yet with regard to alkalis, it has the properties of an acid ; it unites with thofe falts, forms therewith a faline compound which cryftallizes, and even expells the acids that happen to be combined with them ; fo that it decomposes the fame neutral falts that are decomposed by the vitriolic acid.

The fedative falt, when fuddenly expofed to the violent heat of a naked fire, lofes near half its weight, melts, puts on and retains the appearance of glafs : but its nature ftill remains unchanged. This glafs diffolves in water, and fhoots anew into cryftals of fedative falt. This falt communicates to the alkaline falt with which it is united, when in the form of borax, the property of melting with a moderate heat, and forming a kind of glafs ; and it is this great fufibility that recommends the frequent ufe of borax as a flux for affaying ores. It is alfo employed fometimes as an ingredient in the compofition of glafs ; but, in time, it always communicates thereto the fault which its own glafs hath, namely that of tarnifhing with the air. The fedative falt hath moreover the fingular property of diffolving in fpirit of wine, and of giving to its flame, when fet on fire, a beautiful green colour. All thefe obfervations we owe to Mef^{rs}. Geoffroy and Baron.

M. Geoffroy prepares the sedative salt by crystallization only in the following manner. “ He dissolves four ounces of refined borax in a sufficient quantity of warm water, and then pours into the solution one ounce and two drams of highly concentrated oil of vitriol, which makes a crackling noise as it falls in. When this mixture has stood evaporating for some time, the sedative salt begins to make its appearance in little, fine, shining plates, floating on the surface of the liquor. The evaporation is then to be stopped, and the plates will by little and little increase in thickness and breadth. They unite together into little tufts, forming with each other sundry different groups. If the vessel be ever so little stirred, the regularity of the crystals will be disturbed; so that it must not be touched till the crystallization appears to be finished. The crystalline clusters, being grown too bulky and too heavy, will then fall of themselves to the bottom of the vessel. This being observed, the saline liquor must be gently decanted from those little crystals, which, as they are not easily dissolved, must be washed clean, by pouring cold water slowly on the sides of the pan, three or four times successively, in order to rinse out all remains of the saline liquor, and then set first to drain, and afterwards to dry in the sun. This salt, in form of light flakes of snow, is now soft to the touch, cool in the mouth, slightly bitter, crackling a little between the teeth, and leaving a small impression of acidity on the tongue. It will keep long without giving or calcining, if managed according to the preceding directions; that is, if it be exactly freed from its saline liquor.

“ It differs from the sedative salt obtained by sublimation in this respect only, that notwithstanding

“ standing its seeming lightness it is a little heavier than the other. M. Geoffroy supposes the cause of this weight to be, that as several of the thin plates adhere together in crystallizing, they retain between them some small matter of humidity; or, if you will, that, as they form larger crystals, they present less surface to the air, which elevates light bodies: whereas, on the contrary, the other sedative salt, being driven up by the force of fire, rises into the head of the cucurbit in a more subtile form, having its particles much more expanded and divided.

“ M. Geoffroy, having put his sedative salt made by crystallization to all the same trials with that made by sublimation, satisfied himself that there is no other difference between the two. If the sedative salt made by crystallization happens to calcine in the sun; that is, if its lustre tarnishes, and its surface grows mealy, 'tis a sign that it still contains either a little borax or some Glauber's salt; for these two salts are apt to calcine in this manner, and pure sedative salt should not be subject to this inconvenience. In order to purify it, and free it entirely from those salts, it must be dissolved once more in boiling water. As soon as the water cools, the sedative salt re-appears in light, shining, crystalline plates, swimming in the liquor. After standing four and twenty hours, the liquor must be decanted, and the salt washed with fresh water; by which means it will be very pure and beautiful.”

Glauber's salt and borax dissolve in water with vastly more ease than the sedative salt, and consequently do not crystallize so readily by much: so that the small portion of those salts, which may have been left on the surface of the sedative salt, being

being diffused through a large quantity of water, continues in a state of solution, while the sedative salt crystallizes; which being also washed afterwards with fair water, it is impossible that the smallest particle of those other salts should remain adhering to it; and consequently this must be deemed an excellent way of purifying it.

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EXPLANATION of the PLATES.

PLATE FIRST.

FIG. I. *A Copper Alembic.*

- A. The cucurbite or body.
- B. The neck.
- C. The head.
- D. The beak, nose, or spout.
- E. The refrigeratory, or cooler.
- F. Its cock.
- G. The receiver.

FIG. II. *A Glass Alembic.*

- A. The cucurbite.
- B. The head.
- C. The gutter within the head.
- D. The beak.

FIG. III. *A long-necked Glass Alembic.*

- A. The body of the matrafs.
- B. The neck.
- C. The head.

PLATE SECOND.

FIG. I. *A Glass Alembic of one piece.*

- A. The cucurbite.
- B. The head.
- C. The aperture in the head.
- D. Its stopple.
- E. The mouth of the cucurbite.

FIG. II. *A Pelican.*

- A. The cucurbite.
- B. The head.
- C. The aperture in the head, with its stopple.
- D. D. The two curved spouts.

FIG. III. *A Row of Aludels.*

FIG. IV. *A Retort.*

- A. Its bowl.
- B. Its neck.

FIG. V. *An English Retort.*

PLATE THIRD.

FIG. I. *A Reverberating Furnace.*

- A. The ash-hole door.
- B. The fire-place door.
- C. C. C. Registers.
- D. The dome, or reverberatory.
- E. The conical funnel.
- F. The retort in the furnace.
- G. The receiver.
- H. H. Iron bars to sustain the retort.

FIG. II. *The Conical Funnel by itself.*FIG. III. *Back View of a Muffle.*

- A. The bottom of the muffle.
- B. Its arch.
- C. C. C. Lateral apertures.

FIG. IV. *Fore-view of a Muffle.*FIG. V. *A Melting Furnace.*

- A. A. The base of the furnace.
- B. The ash-hole.
- C. D. The grate for the fire.
- E. The fire-place.
- F. G. H. Curvature of the inside of the upper part of the fire-place.
- I. The shaft or chimney.

PLATE FOURTH.

A Cupelling Furnace.

- A. The ash-hole.
- B. B. Its sliding doors.
- C. The fire-place.
- D. D. Its sliding doors.
- E. F. Small apertures in the sliders.
- G. G. Holes for bars to bear the muffles.
- H. H. H. Iron braces in the forepart of the furnace which form grooves for the doors of the fire-place and ash-hole to slide in.
- I. The upper pyramidal part of the furnace.
- K. An aperture therein for managing the coals.

L. The opening at top.

M. The pyramidal cover.

N. The chimney or end of the shaft, on which the conical funnel may be fitted.

O. O. O. O. Handles for moving the sliding doors.

P. P. Ears of the pyramidal cover.

N. B. The furnaces, as represented in the two last plates, are not in due proportion to each other. The cupelling furnace is much larger than it should be, with respect to the melting furnace. These dimensions are here given it, only that all its parts might be more distinctly expressed, than could have been done if we had made it less.

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Fig. 1.



Fig. 2.



Fig. 3.



Pl. II. *Fig. 1.*



Fig. 2.

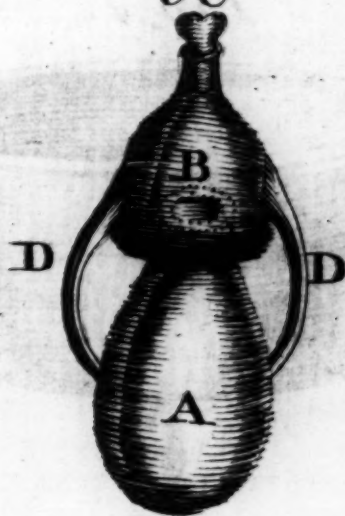


Fig. 3.



Fig. 4.



Fig. 5.



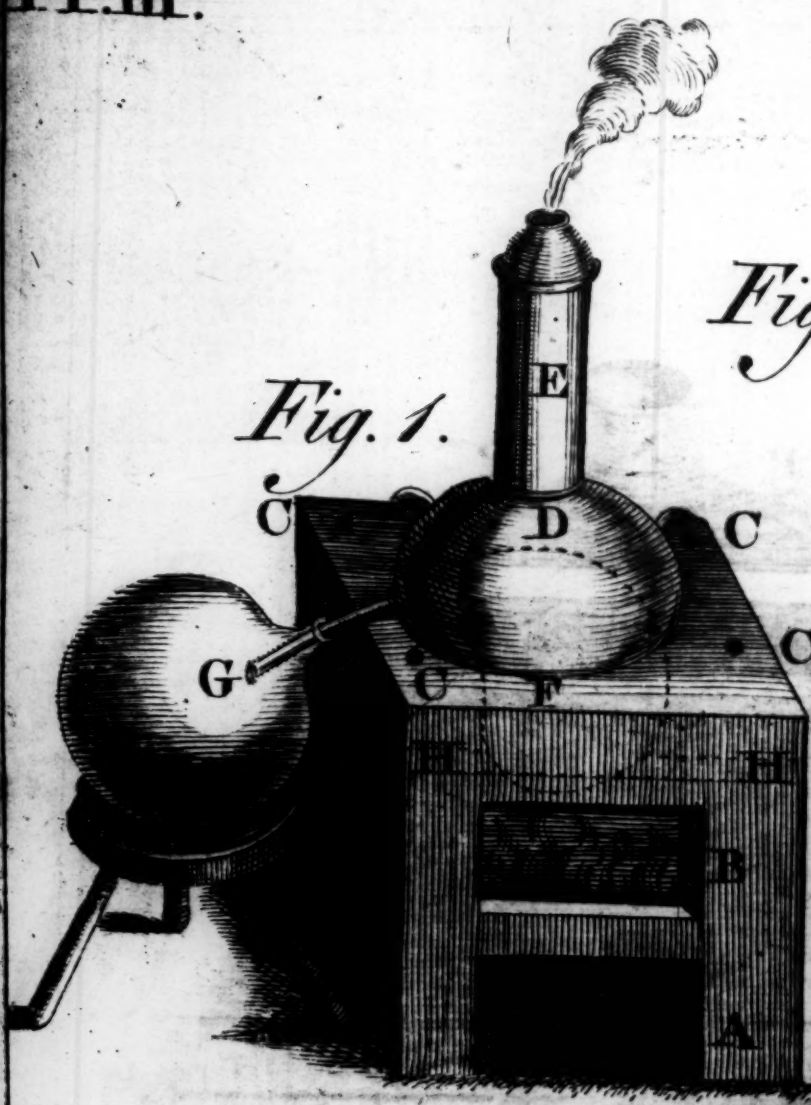


Fig. 1.

Fig. 2.



Fig. 5.



Fig. 3.

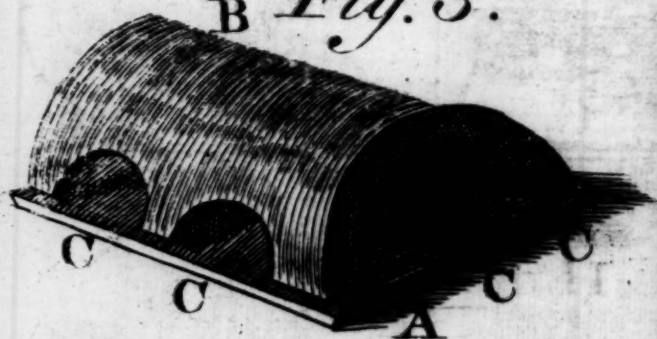
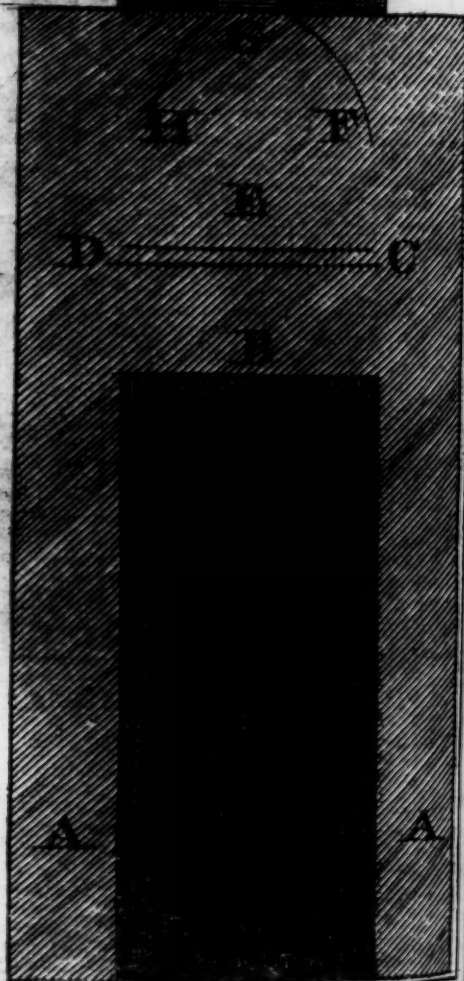
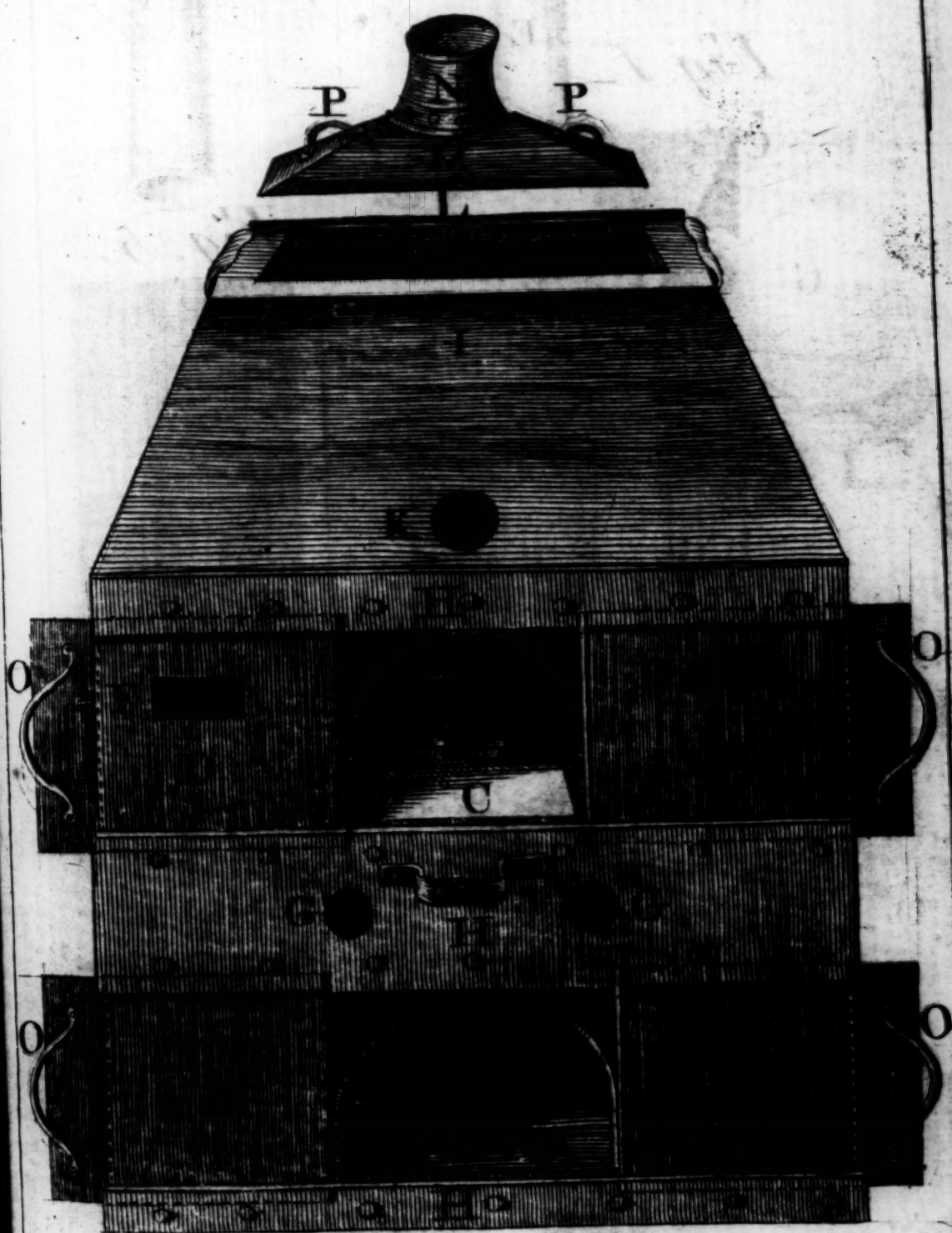


Fig. 4.



PL. IV.



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PIV. *GEOFFROY'S TABLE of the
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I.	II.	III.	IV.	V.	VI.	VII.	VIII.
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Explanation of

Acid Spirits

Marine Acid

Nitrous Acid

Vitriolic Acid

Fixed Alkali

Volatile Alkali

Absorbent Earths

MS *Metallic Substances*

Mercury

Regulus of Antimony

Gold

Silver

PLV *COMPARATIVE AFFINITIES*
fundry Substances.

IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
			LC				
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the Characters

Copper
 Iron
 Lead
 Tin
 Zinc
 Calamine

Sulphur
 Phlogiston
 Spirit of Vinegar
 Water
 Neutral Salts
 Ardent Spirits